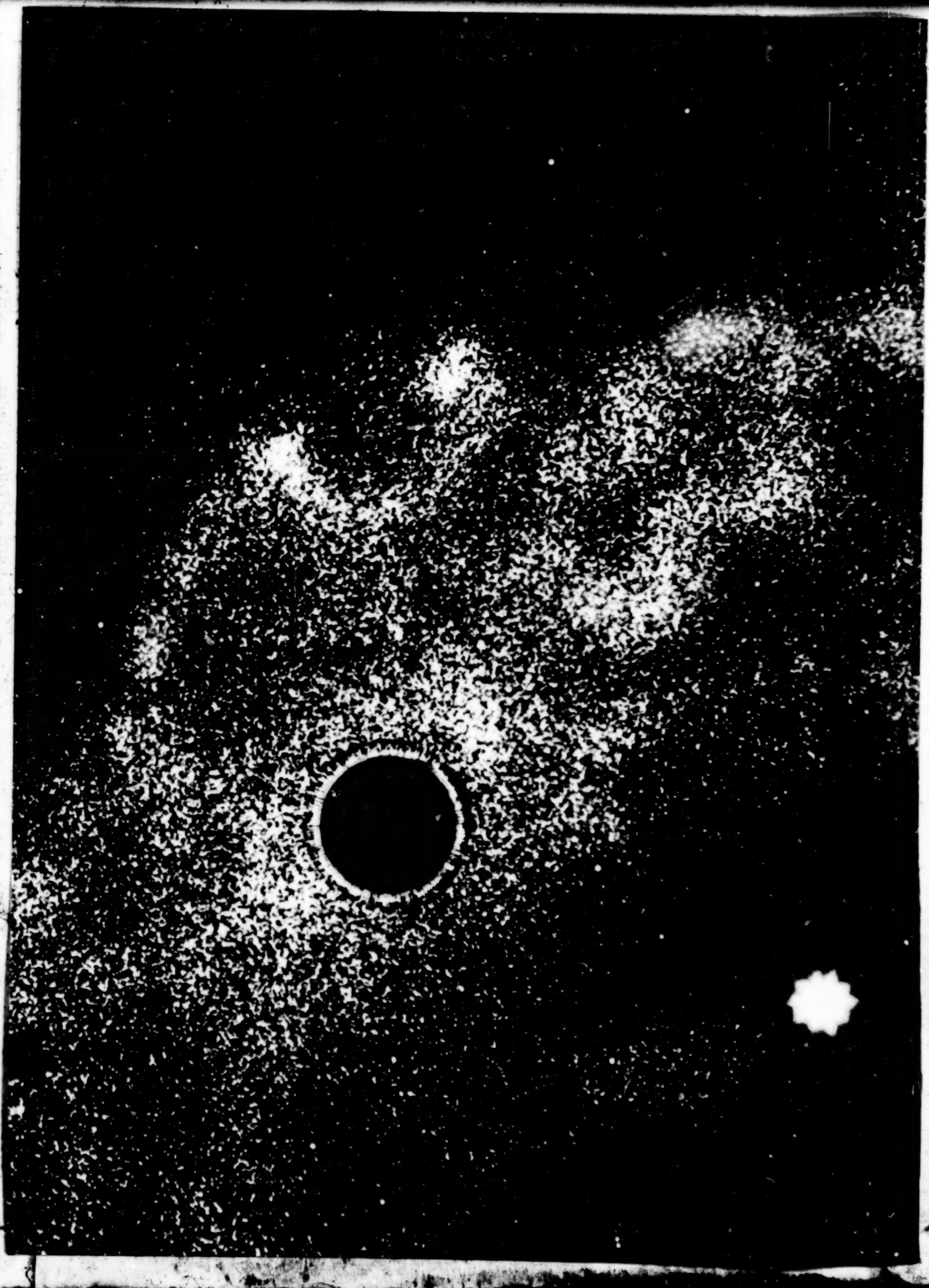
# Spinoff 1994



# Spinoff 1994

National Aeronautics and Space Administration
Office of Space Access and Technology
Commercial Development and Technology Transfer Division

By James J. Haggerty

National Aeronautics and
Space Administration

For sale by the U.S. Government Printing Office
Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328
ISBN 0-16-045368-2

# Foreword

In today's global economic environment, technology is one of the strongest currencies. Over the past three decades, more of the world's nations have recognized the link between technological prowess and economic advancement. They have invested large-scale resources in upgrading their technical capabilities, and in many cases, their efforts have been very fruitful. So today, international economic competition is intense; it is a global engagement whose rewards are greater market shares and improved economic status for the successful contestants.

The United States, long the world's leader in science and technology, must meet the challenges of increasingly competent competitors. The route is clear: We must advance our own capabilities to produce superior products for the global marketplace. It is vital to the nation's economic health and wealth that we do so.

The Clinton Administration is investing heavily in science and technology development, coupled with an effort to stimulate partnerships with industry that promote private sector investment in technological innovation. And NASA, as always, is leading the way.

Since its inception in 1958, NASA has been a prime source of much of the nation's new technology. The agency's accomplishments in technology development have been buttressed by an effective effort to promote re-use, or secondary application, of NASA-developed technologies by the private sector.

The results are impressive. Literally thousands of "spinoff" products and processes have emerged as secondary applications of the technological treasure chest NASA has built in meeting its challenging missions. Collectively, these technology transfers constitute an immense contribution to the U.S. economy.

It is a proud record, but we must do better. We have to stress revolution, not evolution, in creating new NASA technology. More and more, we are going to put out ambitious guidelines for our missions and let industry tell us what cutting-edge technology is needed to accomplish them. We will give our field centers and project managers greater flexibility in funding technology transfer opportunities, and will work to make sure promising technologies translate more quickly and effectively into marketable products and processes.

These new approaches forecast a new, broader role for NASA, a new technological direction and a new way of doing business. We will emphasize research and development partnerships with the private sector. We will consider the economic potential of each technology and aim for its commercialization from the time an R&D project is initiated.

We have already made a start toward that goal. We have developed and are implementing an agenda for change that embraces many new mechanisms to foster commercialization of NASA technology.

As a consequence of these changing times, NASA is committed to expanding its technology transfer efforts in addition to its traditional aeronautics and space missions. The remarkable successes NASA has achieved in those areas lend confidence that the new emphasis on technology commercialization will succeed as well, to the enormous benefit of the nation's economy.

Daniel S. Goldin
Administrator
National Aeronautics and Space Administration

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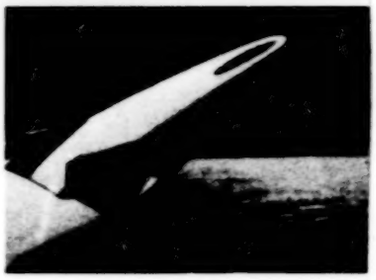
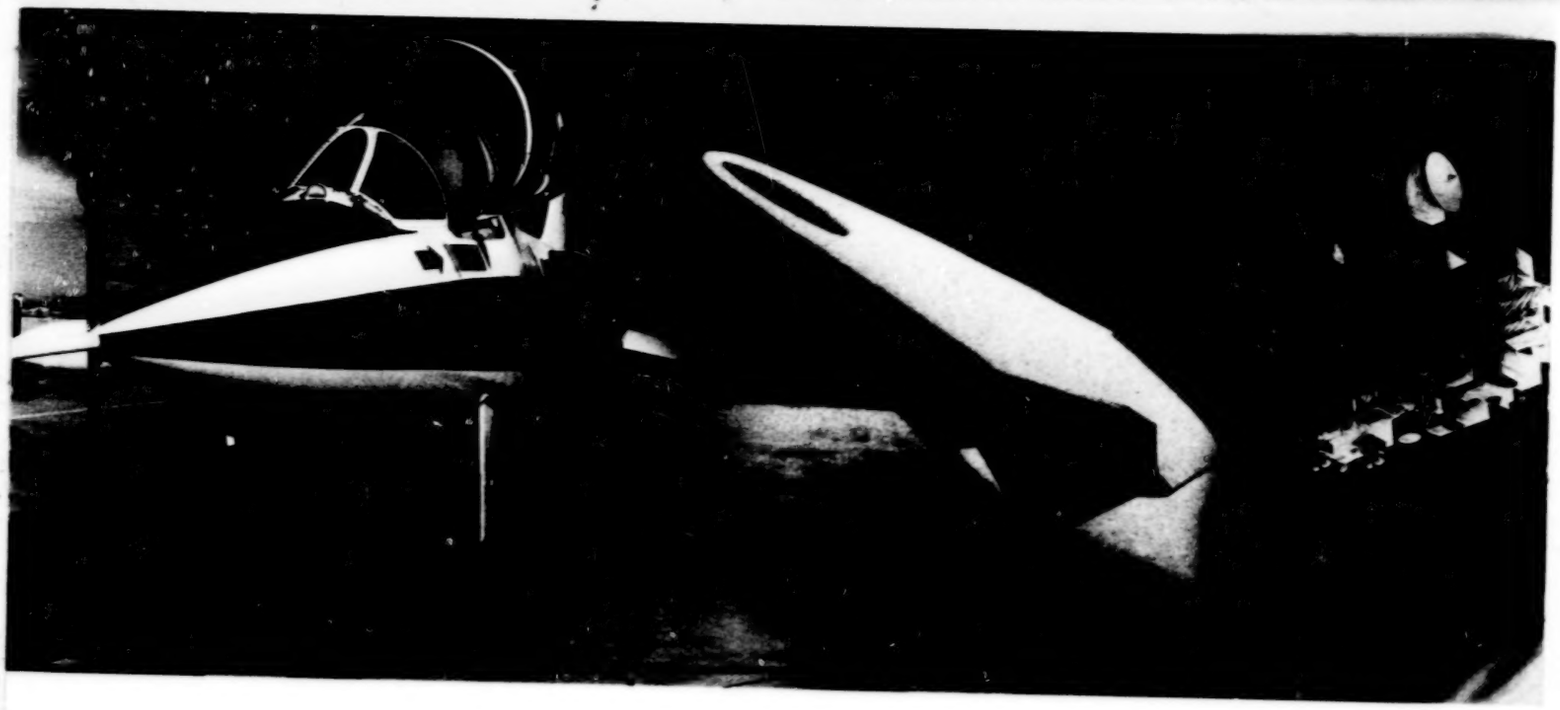




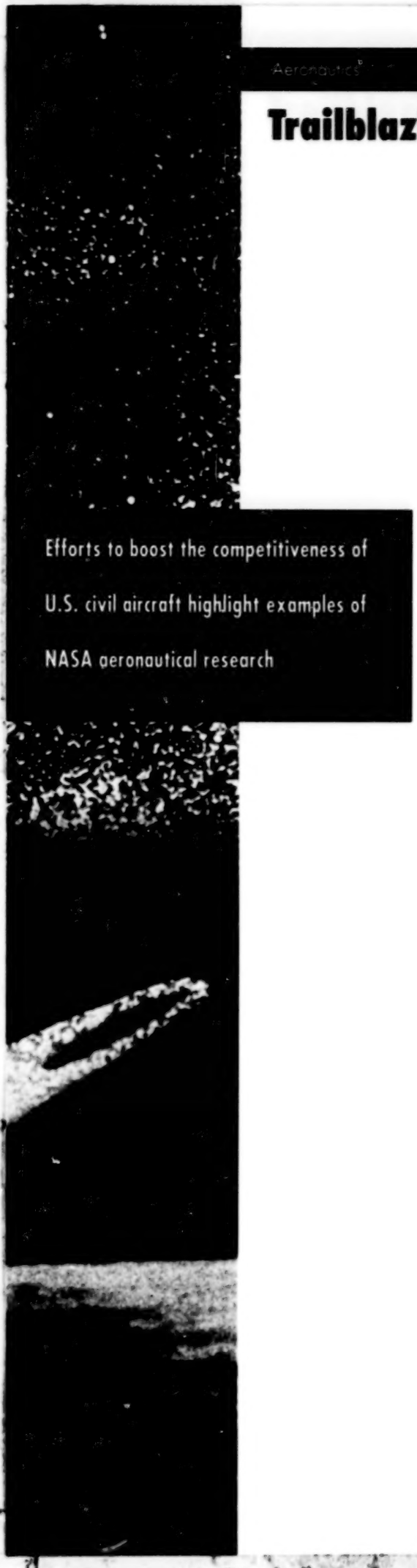




# Aerospace Aims

*An illustrated summary of NASA's major aeronautical and space programs, their goals and directions, their contributions to American scientific and technological growth, and their potential for practical benefit*

# Trailblazing Future Flight



Efforts to boost the competitiveness of U.S. civil aircraft highlight examples of NASA aeronautical research

In 1993, U.S. manufacturers produced more than $26 billion worth of civil aircraft and more than two-thirds of the total represented sales to foreign customers.

That contribution to the U.S. economy underscores the vital importance to the nation of high value civil aircraft sales. But although the production figures are impressive, they are not as impressive as they once were; over the past quarter century, the U.S. has been slowly but steadily losing market share.

The principal reason is intensifying competition from abroad, initially from the nations of Western Europe, more recently from new players in the global arena, such as Russia and its former Communist bloc allies, plus Japan and several industrially-emerging nations of the East. Eyeing the great potential benefits of the world civil aircraft market, all are investing substantially in aeronautical technology development.

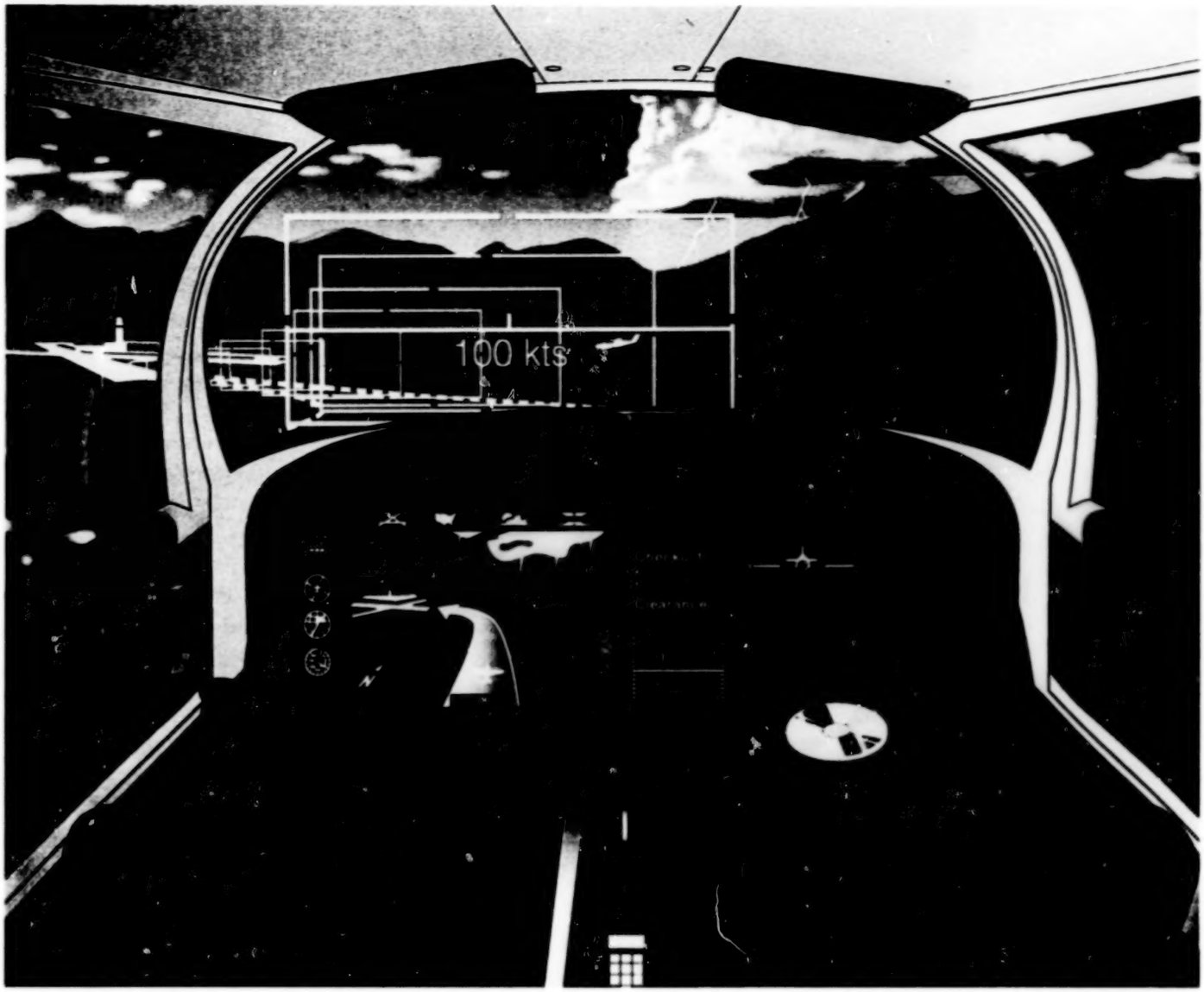
The international market for civil aircraft over the next 20 years is variously estimated at $800 billion to $1 trillion, really staggering numbers that would entail production levels roughly double the average for the last 20 years. The ability of U.S. plane builders to maintain or increase their market share is a matter of consequence to the U.S. economy. Accordingly, NASA is increasing its level of aeronautical research and accelerating its efforts to transfer pertinent technology to the nation's aircraft industry.

The focal point of this effort is NASA's Advanced Subsonic Technology (AST) program, which seeks near term, high payoff technology advances that will increase the competitiveness of U.S. subsonic private and commercial aircraft, including airline transports, general aviation planes and rotorcraft. As part of the AST program, NASA is addressing the specific technological needs of short-haul civil aviation, which embraces two elements: general aviation aircraft and civil tiltrotor aircraft.

General aviation, which includes private and commercial aircraft from the single pilot lightplane to business jets and commuter light transports, has been particularly hard hit by a declining market over the last 15 years. U.S. general aviation manufacturers produced only 850 airplanes in 1993, fewer than five percent of their peak (1978) output of 17,800 planes. General aviation manufacturing jobs are down to 50 percent of their peak level and the industry that once generated an annual trade surplus of $300 million now suffers a trade deficit of more than $800 million a year.

Under the direction of NASA's Aeronautics Advisory Council, an industry/government/academe General Aviation Task Force reviewed the status of the U.S. general aviation industry and — in February 1994 — recommended a balanced NASA general aviation technology advancement program addressing propulsion, noise and emissions, aeronautical systems, structures, and aerodynamic technologies.

In response to the task force reports, NASA has initiated a renewed and expanded effort involving technology development to improve the safety, utility,




environmental compatibility and affordability of general aviation aircraft. Research activities are headed by Langley Research Center and supported by Lewis Research Center and Ames Research center. They center on three key areas:

- Cockpit systems, such as displays, controls and software, that are more user-friendly and cut the time needed to learn and maintain piloting skills.
- Low-cost design and manufacturing methods to make general aviation aircraft more affordable to purchase and operate.
- Quieter propulsion systems with reduced exhaust emissions, and cabins with improved comfort for both pilots and passengers.

NASA also responded with an initiative to address concerns expressed by the general aviation industry. To ensure that industry needs are being addressed, and to maintain strong NASA involvement with industry and the Federal Aviation Administration, NASA is developing Joint Sponsored Research Agreements. These agreements provide a mechanism for making available NASA's "world class tools" —wind tunnels, simulators, computer codes for design and analysis, engine test cells and material property laboratories to the general aviation community.

(Continued)

*NASA technology in development suggests that the general aviation cockpit of the future might look like this. At the pilot's left is a single power lever that replaces multiple levers in today's cockpit. The instrument panel features a wide screen flat panel display that can show weather, flight routes, taxiing and other data. To the right, a smaller display provides engine information and a simplified checklist. Projected on the windscreen is a heads-up display showing the best flight path. A communications system provides automated air traffic coordination.*

## Trailblazing Future Flight (Continued)

*The NASA/Army XV-15 tiltrotor research craft is finding new utility as a flight test bed for advanced proprotor systems designed to minimize noise levels of tiltrotor aircraft.*

Short haul commuter flight is a rapidly growing segment of the U.S. air transportation system; studies indicate that commuter traffic may double by the year 2000. Other studies by NASA and the Federal Aviation Administration show that the tiltrotor type of transport airplane, which combines the unique flight capabilities of the helicopter with the faster forward speed of the fixed-wing airplane, is a viable candidate for service as a shorthaul commuter transport. A market projection by Boeing Commercial Airplane Company sees a potential of $5-7 billion a year in civil tiltrotor sales and a requirement for 4,000 passenger-carrying tiltrotors by 2010.

The tiltrotor offers double promise: it could relieve air traffic congestion by operating from small, near-city "vertiports," diverting shorthaul traffic away from major airports, and it could become a major U.S. export product, because the U.S. has a commanding lead in tiltrotor technology.

Realization of the benefits requires elimination of certain inhibitors to civil tiltrotor operation. NASA's tiltrotor effort, an element of the Advanced Subsonic Technology program, seeks advancement of technologies most critical to development of a commercially viable vehicle.

To meet community noise restraints, the goal is to reduce tiltrotor noise by 75 percent relative to the noise level of the military V-22 Osprey, the most advanced tiltrotor in development. Half of the reduction is expected to come from designing quieter rotors, the other half from optimizing flight paths so that a minimal amount of time is spent at low altitudes over populated areas. Part of this research involves flying the NASA/Army XV-15 research tiltrotor, which has been flying since 1978, as a test bed for advanced proprotor designs in low noise approaches and departures.

The complex flight paths required for low noise operation will probably demand steep angles of approach to vertiports. To reduce pilot workload and create advanced tiltrotor cockpits suitable for safe terminal operations, NASA is performing extensive flight and ground simulations with a Vertical Motion Simulator and the UH-60 RASCAL research aircraft. Technology advances are being made in controls, displays and vision-enhancing sensors, all combined in a fully integrated cockpit designed to reduce pilot workload under all weather conditions in congested terminal areas.

Another objective is to improve passenger comfort by reducing internal noise and vibration to levels comparable to those of modern jetliners. NASA is conducting tests of actuators — located on aircraft skins, engine mounts and transmission mounts — designed to dampen engine and rotor vibration and

noise before it gets to the passenger cabin. Early tests indicate that the goal of a 50 percent noise and vibration reduction is attainable.

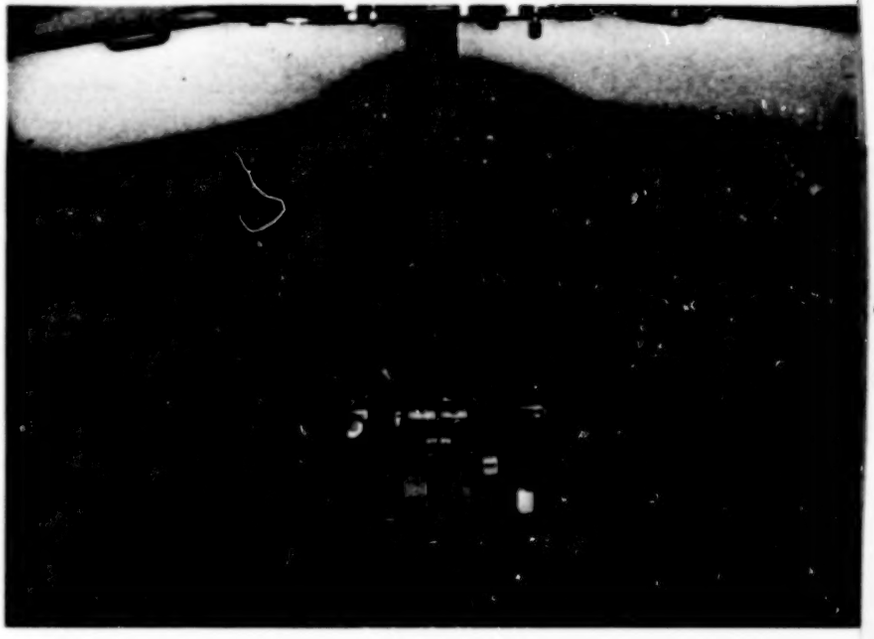
Safety, of course, is a paramount consideration and an essential step is achieving a capability to operate safely with one engine out. NASA is researching different methods of providing substantial emergency engine power. Candidate approaches include advanced turbine cooling, variable turbine geometry and water injection, methods that provide short term emergency power without excessive weight. As with the general aviation/commuter program, the civil tiltrotor technology effort is being conducted on a NASA/FAA/industry partnership basis.

Another element of the Advanced Subsonic Technology program, important to all types of aircraft, is a NASA/FAA cooperative effort known as TAP (Terminal Area Productivity), whose goal is to provide affordable technology for achieving clear weather capacity in a terminal area during instrument weather conditions. Specifically, TAP researchers are looking for ways to reduce safely the required longitudinal distances between aircraft to allow more operations per runway. Additionally, they are studying how to assure more operational runways per airport. Appropriate measures would permit airports to handle the same number of flights in low visibility weather as are handled in clear weather.

Part of the effort focuses on predicting and avoiding wake vortex phenomena. Wake vortices are swirling air currents that stream from an airplane's wingtips and cause turbulence for a following airplane. FAA rules specify separation distances based on aircraft types, weather and visibility, and these separations restrict the number of airplanes that can arrive in or depart the terminal area.

NASA researchers believe that new technology for ground-based sensing of weather conditions will reliably predict when separations can be reduced safely. Such forecasts would be incorporated into an enhanced version of the Center/TRACON Automation System, a NASA/FAA system designed to help air traffic controllers schedule arriving aircraft more effectively. Successful forecasting would give controllers at least 20 minutes notice of weather conditions that would allow closer spacing and increase airport capacity without compromising safety.

Another aspect of the TAP effort involves research toward minimizing traffic delays on the airport surface, during taxiing from the runway to the gate after landing, or from the gate to the runway prior to takeoff. Application of Airport Surface Advisory information delivered to the flight crews could make possible substantial increases in flights during poor weather, decreases in delays, and significant reductions of airline costs.



*NASA is supporting tests of satellite navigation for commercial airlines; in the photo, pilots of Langley Research Center's Transport Systems Research Vehicle, a modified twinjet airliner, are testing an integrated differential navigation system linked to a constellation of navigation satellites.*

# High-Speed Research

Aeronautics

Aircraft and engine manufacturers of several nations are conducting studies toward getting an early jump on the next plateau of international aviation competition: the long range, economical, environmentally acceptable, second generation supersonic passenger transport, which could be flying by 2010.

Market experts predict that a projected quadrupling of traffic to and from the nations of the Pacific Rim, together with more moderate increases in demand for long range passenger transportation in other areas of the globe, will create a need for 500 or more next generation passenger transports worth at least $200 billion and 140,000 jobs.

To boost the competitiveness of American industry in this high-stakes competition, NASA is conducting a High-Speed Research (HSR) program that addresses the highest priority, highest risk technologies needed for an advanced supersonic transport. This program is designed to provide a technology base that will enable U.S. industry to decide whether full scale development of such an airliner is technically and economically viable.

The HSR program is being conducted as a national team effort with shared government/industry funding and responsibilities. The team includes NASA's Langley, Lewis and Ames Research Centers and Dryden Flight Test Center; engine manufacturers GE Aircraft Engines and Pratt & Whitney division of United Technologies; airframe manufacturers The Boeing Company and McDonnell Douglas Corporation; other manufacturers, materials suppliers and academic institutions.

The accompanying photos give an idea of what the future supersonic airliner might look like. Shown undergoing wind tunnel testing is a Boeing design concept known as Reference H, which serves as a common configuration for HSR investigations. The Reference H design would accommodate 300 passengers and cruise at Mach 2.4, about 1,600 miles per hour. **Below,** a model is being "flown" in Langley Research Center's National Transonic Facility, where models are tested at temperatures as low as 250 degrees below zero Fahrenheit; such cryogenic (very low temperature) testing enables simulation of conditions approaching those of full-scale flight. At **right,** a 19-foot model is being readied for test in Langley's 14 by 22 Foot Subsonic Tunnel, which simulates takeoff and landing conditions. Both types of tests are aimed at development of a wing leading edge flap system that improves low speed efficiency and reduces takeoff noise.

Phase I of the program, which focuses on environmental challenges — engine emission effects on the atmosphere, airport noise and sonic boom — got under way in 1990 and will continue through 1996. Phase II, launched in October 1993, involves development of technological concepts that help meet economic and environmental requirements for a successful supersonic airliner.

A most critical technology need is an advanced combustion concept to reduce the nitrogen oxide (NOx) emissions expelled in jetliner exhaust; NOx, reacting with the atmosphere, can cause a chemical reaction that depletes ozone. Research indicates that there are potential operating altitudes in the lower atmosphere where the ozone layer would be minimally affected by a supersonic transport fleet if NOx emissions can be significantly reduced below current levels.

NASA has set a goal of reducing NOx emissions by 90 percent. The key is to burn the fuel in a way that avoids excessive flame temperatures, which generate NOx at a high rate. NASA is testing two especially promising low emission combustor concepts, small scale tests of which suggest that NASA could beat its target of generating no more that five grams of NOx per kilogram of fuel burned at supersonic speed.

Existing supersonic transports, such as the Anglo-French Concorde, have high airport noise levels but they were developed prior to today's stringent noise regula-

ORIGINAL PAGE
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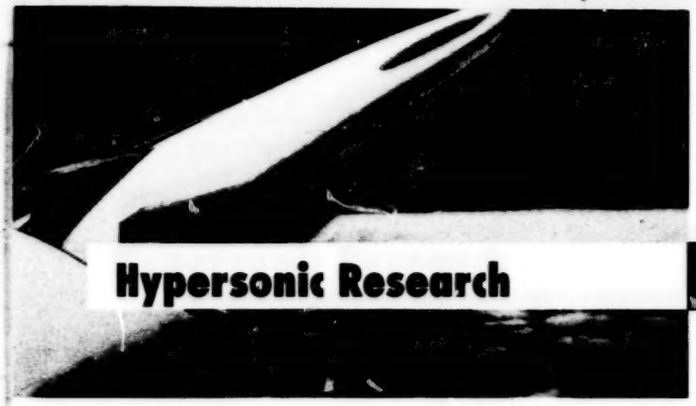
tions. However, it is expected that the next generation supersonic transport will have to meet the same community noise standards as subsonic jetliners.

One approach to noise reduction is an engine design that has lower jet velocity at takeoff, much like the current high bypass turbofans in airline service. But the engine must also provide supersonic performance. NASA, GE Aircraft Engines and Pratt & Whitney are exploring two propulsion concepts that offer reduced takeoff noise without compromising supersonic performance.

Both concepts cut jet noise by mixing low energy "outside" air with high energy exhaust flows during takeoff. The "mixed flow turbofan" concept has a secondary slower-moving airstream that bypasses most of the engine's turbo-machinery but rejoins the main airflow before it reaches the exhaust nozzle. The other concept, known as FLADE for "fan on blade", is a modified turbofan that introduces an additional (third) airstream up front in the engine fan. NASA and the engine manufacturers will explore both concepts until 1996, when one will be selected for focused technology development.

In other important areas of the HSR program, NASA is trying to soften the sonic boom caused by shock waves generated in supersonic flight by "boom shaping," aerodynamic shaping of wing and fuselage sections to reduce the apparent boom at ground level. The problem of extremely high drag caused by air friction at speeds of Mach 2 and beyond is being addressed by an investigation of improving laminar (smooth) airflow at supersonic speed; the approach involves use of suction to siphon off the turbulent air very close to the surface of the wings, thus smoothing the airflow. The HSR team is also researching systems for an ultra-high-tech supersonic airliner cockpit that would use advanced sensors and computer generated displays to create "synthetic vision" for the flight crew during nose-high landings; this would eliminate the need for "drooping" the aircraft's nose, as is done on the Concorde, thereby saving the substantial weight of the complex drooping mechanism.



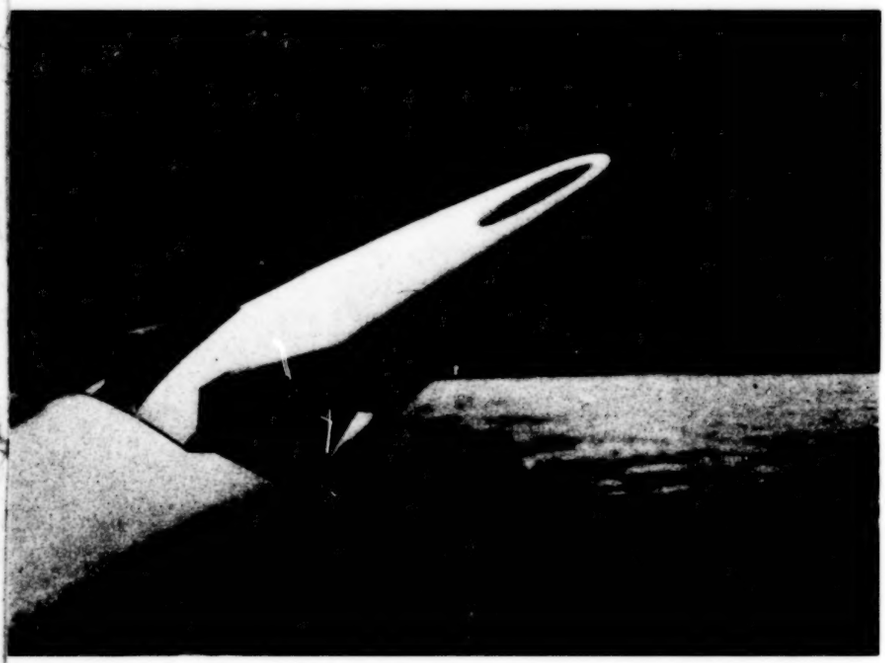
# Hypersonic Research



An important part of NASA's aeronautical research involves development of technologies for future vehicles capable of hypersonic flight, which by definition is flight faster than five times the speed of sound (Mach 5).

The hypersonic vehicles contemplated would take off like an airplane, fly to high altitude or into Earth orbit using airbreathing engines most of the way, then return to Earth to land on a runway. They would offer access to space or hypersonic flight within the atmosphere with airplane-like flexibility and responsiveness. They would be fully reusable, and because they would not need the extensive facilities and support personnel required for vertical launches, they promise reduced operating cost and much shorter turnaround time than is possible with the Space Shuttle.

NASA has long been engaged in research toward craft of this type, in its own hypersonic research program and in the joint NASA/Department of Defense National Aero-Space Plane Program (NASP). NASP research contributed a wealth of technology in such areas as hypersonic propulsion, cryogenic fuel, materials and structures, computer science and integration of engines with hypersonic airframes. Due to limited resources, the NASP program was concluded on September 30, 1994, the end of Fiscal Year 1994.



With the start of FY 1995, NASA and the Air Force launched a new, more focused hypersonic technology effort that builds on NASP and earlier NASA hypersonic research. The new program is known as the Hypersonic Systems Technology Program (HySTP, pronounced High Step). Its main goal is to demonstrate the performance and operability of scramjet (supersonic combustion ramjet) propulsion systems at very high speeds. Scramjets, which burn a mix of hydrogen carried aboard the vehicle and oxygen scooped up from the atmosphere, are widely regarded as the most efficient type of engines for a fully reusable aerospace craft.

HySTP plans call for a combination of flight tests and ground experiments. Researchers are using advanced supercomputing techniques to generate better simulations of combustion processes inside scramjet engines. Additional data will be acquired by tests of the one-third scale Concept Demonstrator Engine, a NASP engine model that has been operated at Mach 8 flight conditions in a special NASA wind tunnel. In addition, NASA experiments piggybacked on Pegasus air-launched satellite boosters will yield new data on aerodynamic flows at Mach 6.

Because ground experiments cannot fully simulate the flight environment above Mach 8, HySTP will include flights of a medium-scale scramjet engine to test conditions at Mach 15; the scramjets will be boosted by surplus intercontinental ballistic missiles. The first launch is targeted for 1997; NASA and the Air Force plan two or three additional flights before the turn of the century. Flight data from these tests will verify computer design methods for scramjet performance at the highest speeds, greatly reducing risks for development of future airbreathing aerospace planes. Actual construction of a research X-plane to explore the full range of hypersonic flight conditions, the ultimate goal of NASP, remains a longer term objective of NASA's hypersonic research.

# High Performance Computing

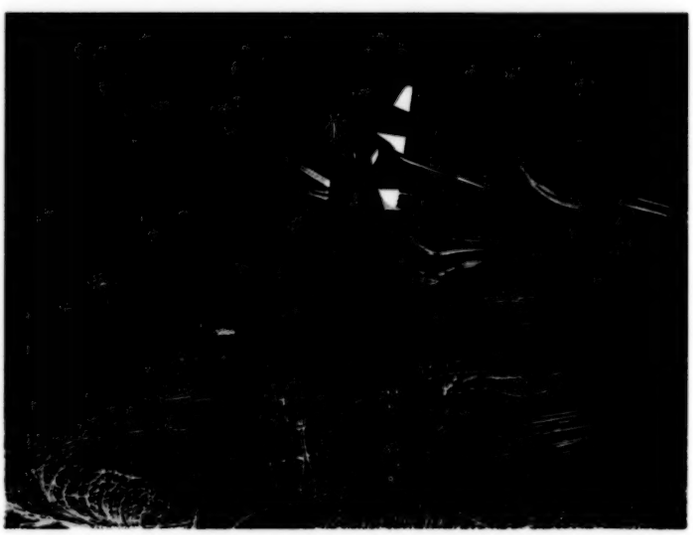
High performance computing is vital to NASA's progress in science and engineering; it is essential to support many of NASA's programs in all phases, from conceptual design to analysis to mission operations. Computer design techniques are widely employed to create mathematical models of flight vehicles and "fly" them by computer simulation. In Earth sciences and space sciences, supercomputers have enabled NASA to make significant strides in weather/climate research, galactic evolution studies, and solid Earth modeling.

High performance computing is similarly important to the competitiveness of the U.S. aerospace industry, particularly in development of commercial aircraft, sales of which amounted to more than $24 billion in 1993. Rapid, accurate prediction of the resistance caused by air flowing over an airplane — drag — is fundamental to aircraft design, but today's simulations do not accurately predict high drag. High performance computing can make possible inexpensive, accurate, 15-minute simulations of aircraft drag; among the benefits are superior aircraft design, reduced certification costs, improved reliability and reduction of the design process time.

To help bring about the advanced supercomputing capability needed, NASA is conducting a High Performance Computing and Communications (HPCC) program as part of a broader federal HPCC effort intended to support a broad range of economic and social goals. The immediate aim of the NASA HPCC program is achievement of sustained computational speeds of one trillion floating point operations per second by 1997. An evaluation of supercomputing needs beyond 1997 concluded that computational speeds 1,000 times greater will be required to fully meet future aeronautics and space science goals and the HPCC program is designed to attain that objective.

One approach to faster computing is parallel processing, in which a large number of processors work simultaneously on a problem. In the spring of 1994, NASA took a major step toward advancing capability in this area when it contracted with a newly-organized consortium — headed by International Business Machines Corporation, Somers, New York — to research and test advanced computer systems using parallel processing technology.

Ames Research Center, NASA's lead center for supercomputer research, is the principal computational site for the new program. IBM will provide three new SP-2 parallel computer systems for cooperative research with NASA's Computational Aeroscience Project, which is part of the HPCC program. The main computer testbed will be located at Ames' Numerical Aerodynamic Simulation facility, a national supercomputer complex linked to more than 1,200 industry/university/government scientists by its national computer network, AERONet. Small development computers will be located at Langley Research Center and at Rice University in Houston, Texas.



# Flight Research

Aeronautics

Shown at **left** is NASA's F/A-18 Systems Research Aircraft on the initial flight (October 1993) of a new program involving tests of a fiber optic control system that could result in lighter, more fuel efficient airplanes with improved control and monitoring capability. Being conducted at Dryden Flight Research Center, the tests are part of NASA's Fly-By-Light/Power-By-Wire program aimed at development of advanced control and management systems for future civil transport aircraft.

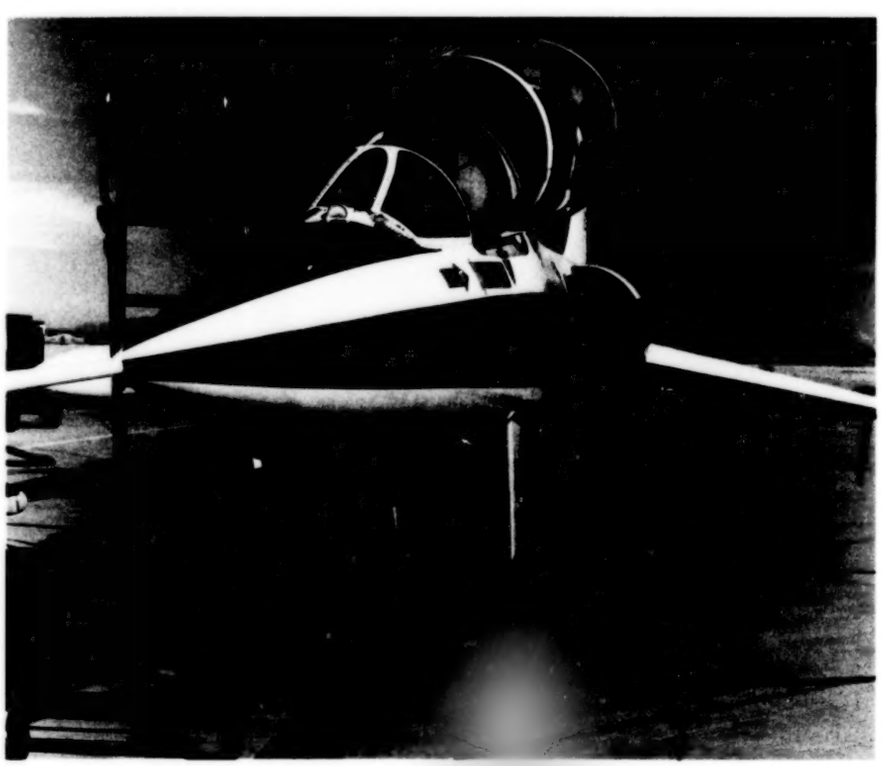
The Systems Research Aircraft is representative of a fleet of research aircraft operated by NASA to explore new technologies and new flight regimes, usually in cooperation with U.S. industry the Department of Defense, including the Air Force, Navy, Army and the Advanced Research Projects Agency, and sometimes in cooperation with international development teams.

Fiber optic systems are small bundles of light transmitting cables that weigh less and take up less space than the copper wiring used in today's aircraft to carry signals to and from flight controls. Fiber optics also have better immunity to strong radio signals and lightning, they are free from short circuit arcing, and they can carry more electronic signals. There is an additional weight saving in substituting fiber optics for copper because the long copper cables must be shielded with insulation to protect other aircraft systems from signal "leaks."

Use of fiber optics would also permit signals to travel more quickly between locations in an airplane, because fiber optic cables do not have the built-in resistance to electricity running through them that copper cables have. Dryden and Lewis Research Center, in cooperation with the U.S. Navy, have been working on fiber optic control system integration since 1985.

Another example of flight research at Dryden involved 1994 tests of an optical viewing system that would allow pilots of high speed aircraft to see the runway during nose-high landings without relying on complex mechanical structures or computer-generated views.

Pilots of supersonic aircraft usually land at high angles of attack to maintain the descent rate at low speeds; that could block runway visibility at a crucial time. Designers solved the problem in the Anglo-French Concorde supersonic jetliner by "drooping" the entire nose section forward of the windscreen, but this approach involves a penalty in the heavy, complex drooping mechanism. Other options would be to equip a supersonic aircraft with high definition video cameras or sensors or use computer generated imagery to provide a view of the runway; however, these approaches rely on the durability of delicate electronic components, and video cameras have only one-hundredth the resolution of the human eye.



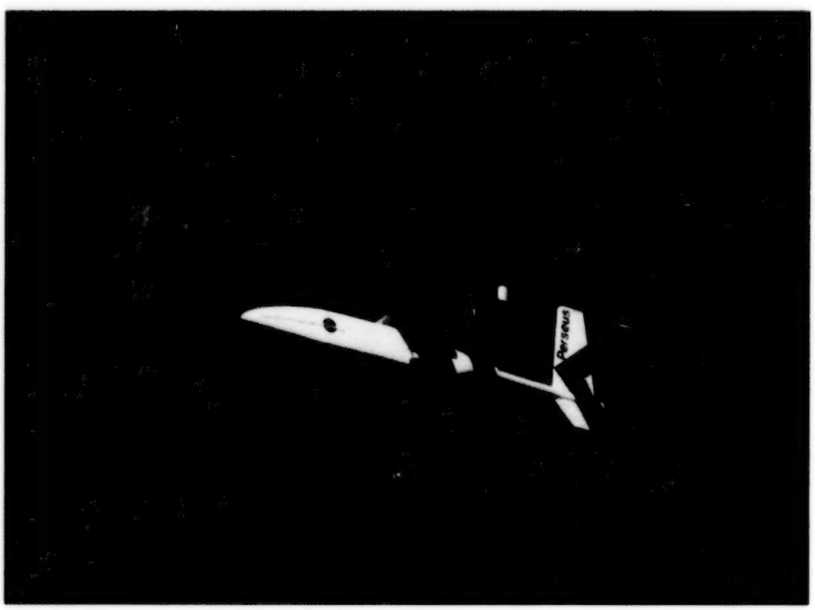
The system tested is known as the Research External Vision Display (REVD), an arrangement of lenses and mirrors that reflect a view of the runway to the pilot. REVD, which is described as "an upside-down periscope," needs no electronics or video cameras and has no moving parts. The REVD installation is shown at **left** on a modified two-seat F-104 research aircraft. The lower part of the REVD system, which looks out from beneath the aircraft and reflects the view up to the pilot in the rear seat, is enclosed in the fairing extending from the fuselage just below the forward seat. The viewing portion of the periscope is pictured **above**. Future designs may eliminate the fairing, which juts out into the airstream; this could be done by recessing the REVD into the fuselage or by designing a retractable device that would drop down during landings.

The REVD program was a joint effort by Dryden, Ames Research Center, the Air Force, Lockheed Fort Worth (Texas), Kaiser Optical Electronics of Carlsbad, California, and Systems Technologies, Inc., Mountain View, California.

Shown at **right** is the Perseus unmanned aerial vehicle during its initial flight at Dryden (December 1993). Perseus is designed to carry scientific payloads to high altitudes for studies of atmospheric conditions; the data collected will bridge a gap between satellite measurements and data from research aircraft.

Perseus was designed and built by Aurora Flight Sciences Corporation, Manassas, Virginia. Much of the technology that enables the craft to carry a 110-pound payload to very high altitudes derives from sport aviation and from the Daedalus aircraft that broke several world records for human powered flight in 1988.

Powered by a four-cycle, four cylinder Rotax engine, Perseus is towed into the air by a ground vehicle. It can be remotely piloted from a ground station, but it will usually fly automatically along a preprogrammed flight path. An on-board computer tracks the plane's position by processing signals from Global Positioning System navigation satellites. In operational service, Perseus will gather atmospheric readings at 65,000 to 82,000 feet.



# Probing the Universe

NASA's space science program seeks expansion of human knowledge about Earth and its place in the universe

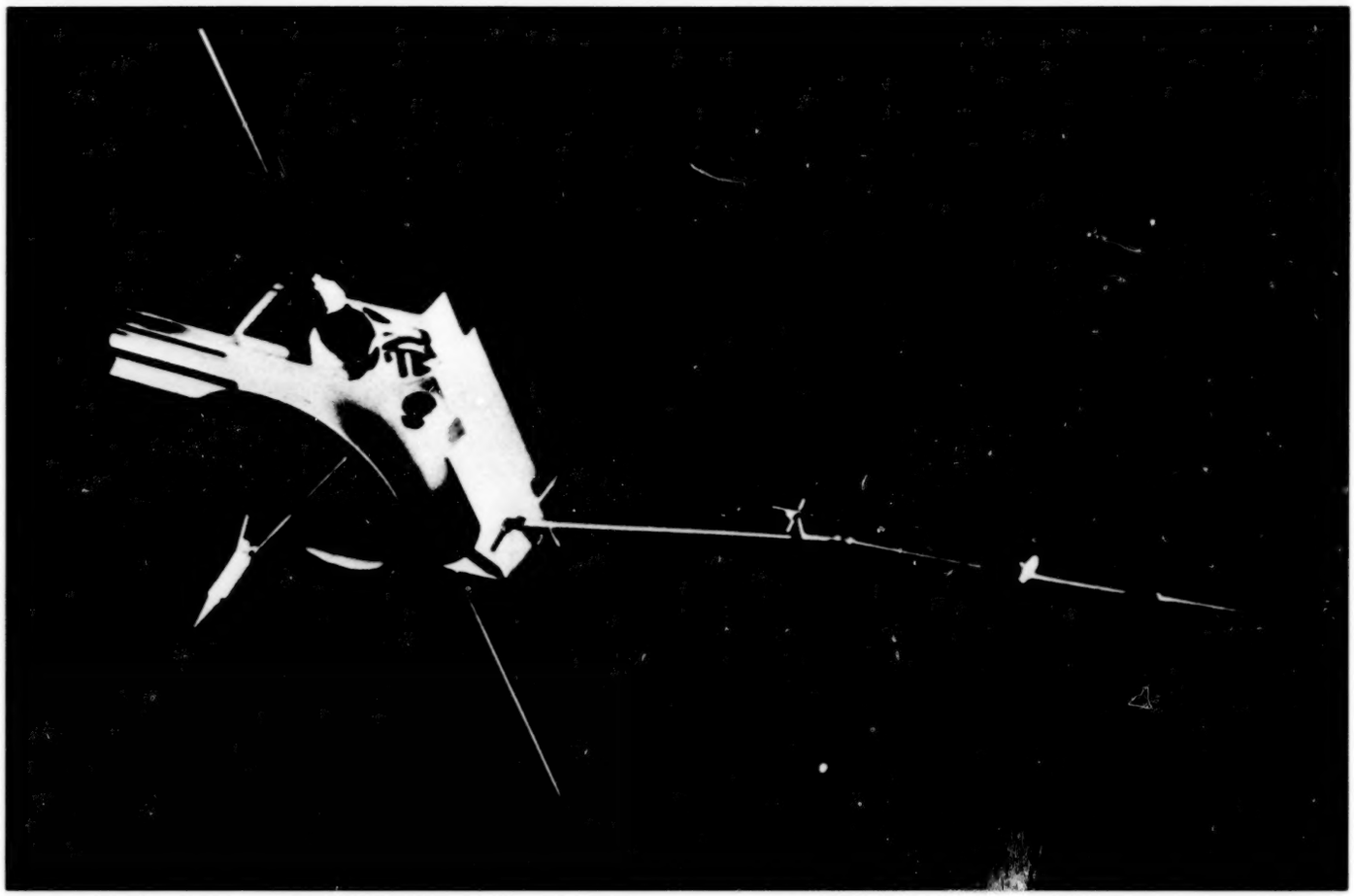
In June 1994, the Ulysses spacecraft made history when it became the first robotic space exploration vehicle to reach a polar region of the Sun. The spacecraft, built by the European Space Agency (ESA) for the joint ESA/NASA mission to study the solar polar areas, passed over the vicinity of the south pole after a four-year journey from Earth on June 26 and began a four-month study of the complex forces at work in the southern polar region. Ulysses' mission is of utmost importance to science, because it enables the first direct solar polar observations and promises to illuminate many long-standing solar mysteries.

For years scientists have suspected that many of the solar phenomena observed were controlled by conditions in the Sun's polar regions. However, until Ulysses they had never been able to observe these processes, first because Earth-based instruments and Earth-orbiting spacecraft offer only limited views of the Sun, and secondly because many solar phenomena cannot be observed remotely but require direct measurements.

Scientists at ESA and Jet Propulsion Laboratory, which manages the U.S. portion of the Ulysses project, hope to acquire a wealth of new data on such important areas of solar science as the Sun's magnetic fields; the corona, the Sun's outer atmosphere, and the unknown source of the heat that creates the corona; the escape and acceleration of the solar wind, the stream of hot gas that courses outward from the Sun through the solar system; and the intensity and properties of cosmic rays arriving in the vicinity of the Sun from the Milky Way Galaxy and the nearby interstellar medium. Key to the scientific quest is a better understanding of the Sun's magnetic field, because it influences -- and perhaps modifies -- the corona, the solar wind and incoming cosmic rays.

According to the mission plan, Ulysses was to complete its investigation of the southern polar area in October 1994, continue in orbit across the Sun's equator (February 1995) and on to the north polar region to begin a similar study in May 1995. Ulysses' primary mission ends after it completes the northern passage in September 1995 but, if funding is available, mission scientists would like to continue collecting data through an entire 11-year solar cycle.

The Ulysses mission exemplifies one aspect of NASA's broad space science program: solar system exploration with robotic spacecraft. Other major science divisions are astronomy/astrophysics, the study of stars and galaxies toward an understanding of the origin and evolution of the universe, and space physics, which centers on the Sun/Earth relationship. In the broader sense, space science also includes Earth science and application studies grouped under the Mission To Planet Earth, NASA's effort to broaden understanding of the factors that influence Earth's environment and develop ways to use that knowledge for mankind's benefit. Additionally, the term space science embraces life sciences and microgravity science and applications, areas of investigation covered elsewhere in this volume (see page 32).



*In orbit around the poles of the Sun, the Ulysses spacecraft is making the first direct observations of the Sun's polar regions, a mission of immense scientific importance.*

In addition to Ulysses, there are several other currently active solar system explorers, notably the Galileo spacecraft en route to Jupiter for an extended study of the planet and its moons (see page 18). NASA is also developing a number of advanced spacecraft for future solar system exploration.

The major development program is Cassini, a joint NASA/ESA mission to Saturn and its moon Titan. The Cassini spacecraft, consisting of an orbiter and a probe, is to be launched in October 1997; it will arrive at Saturn in June 2004 to begin a four-year orbital survey, during which it will conduct 60 close flybys of Saturn's moons and provide data on the planet's atmosphere, magnetosphere and rings. It will also send the instrumented ESA probe -- named Huygens -- into Titan's atmosphere, which is believed to be chemically similar to the atmosphere of early Earth and is thus of immense scientific interest.

Also in development is NASA's Discovery program, which contemplates lower cost, more frequent missions to the planets by small spacecraft. The first Discovery mission is the Near Earth Asteroid Rendezvous (NEAR). To be launched in February 1996, NEAR will rendezvous with the largest of the near-Earth asteroids -- 433 Eros -- to conduct a one-year scientific study. In December 1996, NASA will launch the Mars Pathfinder, which will serve as a science and engineering test vehicle for a series of future Mars landers; it includes a "microrover", a small, inexpensive vehicle designed to roam the surface and send back to Earth three-dimensional images of the Martian landscape.

NASA has initiated a companion program known as Mars Surveyor that starts with development of a small Mars orbiting spacecraft to conduct a two-year mapping operation beginning in January 1998. NASA envisions sending a series of orbiter/lander pairs to Mars to take advantage of launch opportunities that occur about every two years as Mars comes into alignment with Earth.

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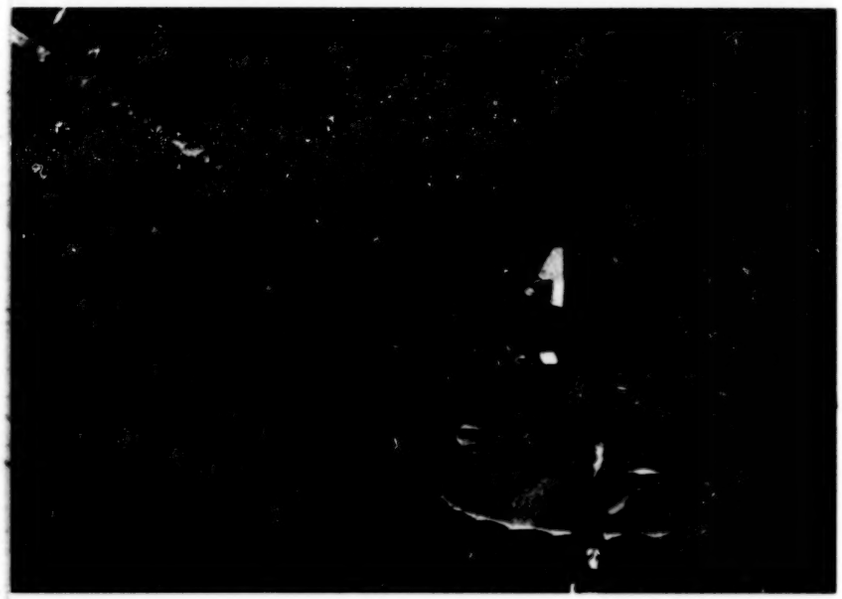
## Probing the Universe (Continued)



*En route to Jupiter for an extended investigation of the solar system's largest planet, the Galileo spacecraft made history by photographing the only two asteroids viewed in closeup. Galileo will reach Jupiter in December 1995, release an instrumented probe into the Jovian atmosphere, then swing into orbit around the planet.*

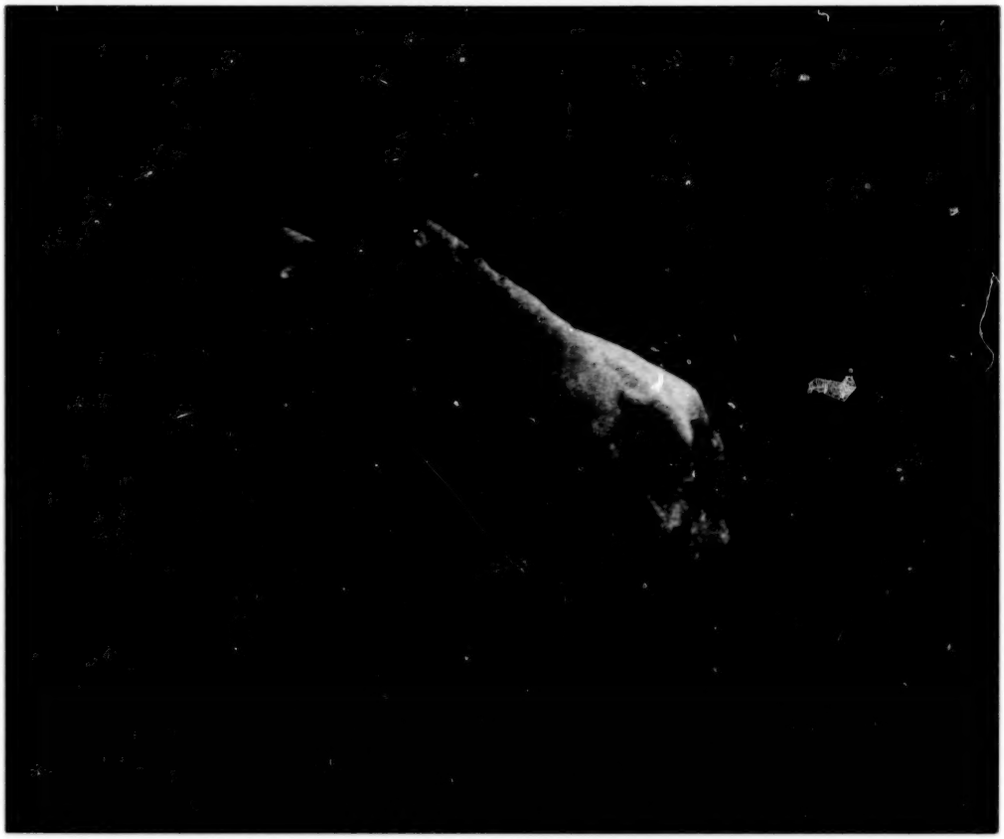
Launched in 1990 on a six-year roundabout journey to the planet Jupiter, the Galileo spacecraft accomplished a scientific coup by taking the first ever photograph of an asteroid's moon. The historic imaging occurred on August 26, 1993, when Galileo flew past asteroid 243 Ida, the second of two asteroids encountered by Galileo (the first was Gaspra, photographed in 1992).

From Galileo imagery and spectrometry data, scientists estimate that the tiny moon measures about one mile across and appears to be orbiting the asteroid at a distance of about 60 miles. Ida itself measures 35 by 15 by 13 miles. Galileo's closest approach to the asteroid was 1,500 miles.

By midyear 1994, Galileo had completed more than 90 percent of its journey to Jupiter. The spacecraft will reach Jupiter in December 1995, at which time it will release an instrumented probe that will descend into the Jovian atmosphere and report data on the atmosphere's composition. The main spacecraft will then swing into orbit around Jupiter, imaging the planet and its moons with greater resolution than was possible with predecessor planetary spacecraft. Galileo is a cooperative U.S./Germany project managed for NASA by Jet Propulsion Laboratory (JPL). The main spacecraft was designed and built by JPL; Ames Research Center has management responsibility for the probe, which was built by Hughes Aircraft.

Galileo is one of seven NASA planetary/interplanetary spacecraft active in 1994; the others are Ulysses (see page 19), Magellan, Pioneers 10 and 11, and Voyagers 1 and 2 (the Venus-orbiting Magellan spacecraft was still active in Fiscal Year 1994 but scheduled for deactivation early in FY 1995).

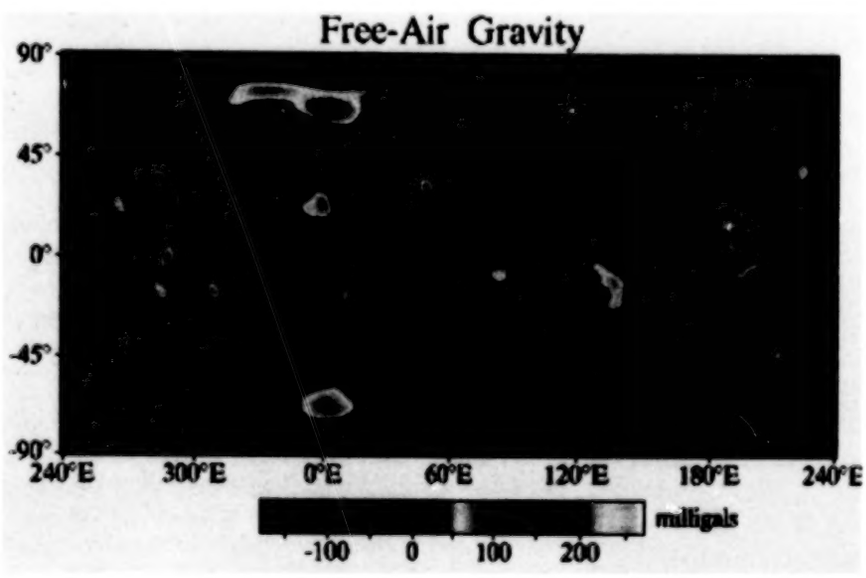
Magellan measured gravity using only the spacecraft's radio signal in a technique that allows Earth controllers to measure the spacecraft's speed in orbit (Magellan's velocity increases over regions of high density and slows over regions of lesser density). A study of Magellan's gravity data, conducted by JPL's Dr. Suzanne Smrekar, suggests that Venus is still geologically active in some places. The gravity readings showed evidence of "top loading" and "bottom loading" at several locations. Top loading indicates the presence of a large mass, such as a mountain or a volcano, pushing up on the crustal plate. Bottom loading indicates a "hot spot," an area where there is an upwelling of less dense -- and therefore hotter -- material beneath the surface. Gravity-related images produced in conjunction with Dr. Smrekar's study show the density variations on Venus as measured in milligals. The largest positive gravity effects measured about 200 milligals and pointed out areas where hot spots exist (see image at right).



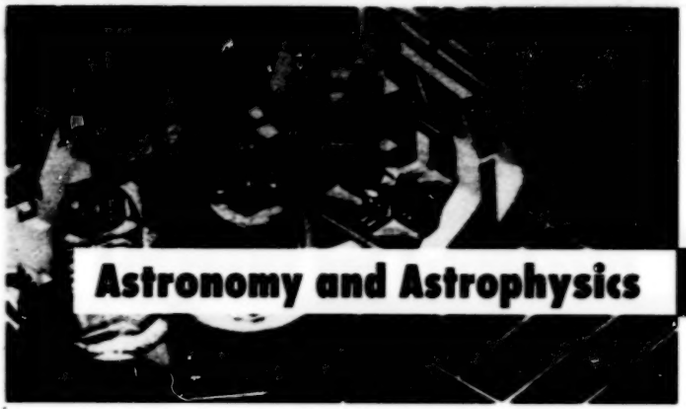
*A historic image: the first-ever photo of an asteroid's moon, taken by the Galileo spacecraft. The asteroid is known as 243 Ida. The tiny moon, measuring about one mile across, is visible to the right of the asteroid; it is apparently orbiting Ida at a distance of about 60 miles.*

Four veteran spacecraft -- the two Pioneers launched in 1972 and the two Voyagers who started their grand tour of the solar system in 1977 -- are still in contact with Earth and conducting a scientifically important search: they are looking for the boundary between the solar system and interstellar space. The four spacecraft are also relaying measurements of the solar wind and the interplanetary magnetic field at distances very far from the Sun. Pioneer 10, the man-made object most distant from Earth, is 59 Astronomical Units (AUs) away (an AU is the average Sun-Earth distance, about 93 millions miles); it is expected to continue functioning until 1997. The companion Pioneer 11 will run out of power in the spring of 1995.

Since the heliopause (the solar system/interstellar space boundary) is estimated at 110 AUs, the Pioneer will probably have lost contact with Earth when they reach that distance, so the job of reporting discovery of the heliopause will fall to Voyager 1 (55 AUs) and Voyager 2 (42 AUs). The Voyagers will be able to provide data for another 20 years or more; it is estimated that they will physically encounter the boundary sometime between 1998 and 2008.




*This image, produced by gravity data from the Magellan Venus-orbiting spacecraft, shows the density variations on Venus as measured in milligals; the colors red and white depict the areas of largest positive gravity effects. A study of Magellan's data suggests that Venus is still geologically active. The red blob near the equator at far right of the image indicates an active hot spot, or volcano, at a site known as Atla Regio, where Magellan registered about 200 milligals, the highest rating found. Beta Regio, in the upper left hand corner of the image, also registered 200 milligals.*

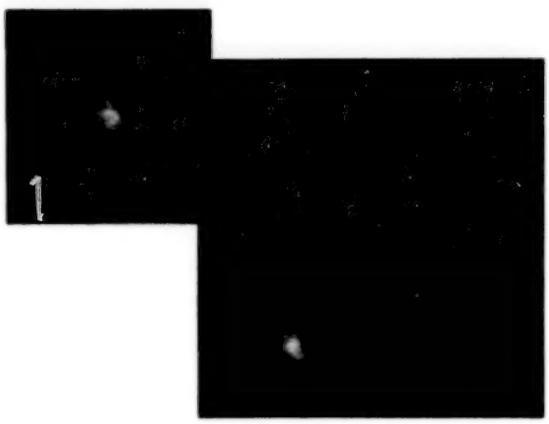


# Astronomy and Astrophysics



Its vision fully corrected by the December 1993 Space Shuttle servicing mission (see page 30), the Hubble Space Telescope (HST) continued to live up to its reputation as a "true national treasure," a term applied by NASA Administrator Daniel S. Goldin. Managed by Goddard Space Flight Center, the HST began its fifth year in orbit in April 1994 and, as in previous years, was regularly providing astronomers exciting new discoveries about the cosmos.

Examples of the types of scientific information the HST is providing are shown in the accompanying images. **Below** is a striking image acquired by the HST's Wide Field Planetary Camera 2 showing three rings of glowing gas encircling the site of Supernova 1987A, a star that exploded in 1987. The HST had earlier identified the center ring but the view of the outer rings surprised scientists. What produced them is not known; one possibility is that they had been "painted" by a high-energy beam of radiation or particles, like a searchlight sweeping across clouds. The source of the radiation might be a previously unknown stellar remnant that is a binary companion to the star that exploded in 1987.



The HST will conduct further observations to determine whether a companion remnant really exists. Supernova 1987A is 169,000 light years distant, located in a dwarf galaxy known as the Large Magellanic Cloud.

Another of the HST's discoveries is illustrated **above**, an image of a spiral-shaped disk of hot gas in the core of Galaxy M87, where astronomers have long suspected that some unusual activity was taking place. Earlier HST observations had found evidence of a massive black hole in the core of M87; the 1994 imagery is more conclusive evidence that the black hole does, in fact, exist. A black hole is an object so massive yet compact that nothing can escape its gravitational pull, not even light. The mass at the center of M87 may weigh as much as three billion Suns, but it is concentrated in a space no larger than our solar system.

The HST's discovery is based on velocity measurements of the whirlpool of hot gas that makes up the disk observed. The disk is rotating so rapidly it signifies the presence of a tremendous gravitational field -- but the region contains only a fraction of the number of stars it would take to create such a powerful attraction. Therefore, there must be some other source of attraction that cannot be seen, such as a black hole. Galaxy M87 is 50 million light years away in the Constellation Virgo.

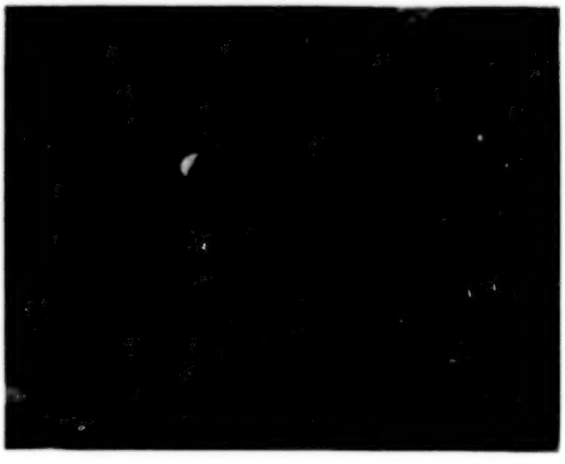
The HST also shed new light on the question of whether the process by which planets are formed is common in the Milky Way Galaxy. Apparently it is, according

to evidence found by Rice University astronomer Dr. C. Robert O'Dell using HST data. O'Dell reported that great disks of dust -- the raw material of planet formation -- are swirling around at least half and probably more of the stars in the Orion Nebula, a region only 1,500 light years from Earth where new stars are being born.

A HST image of a small portion of the Orion Nebula **(below)** reveals five young stars. Four of them are surrounded by protoplanetary disks, or "proplyds." The disks are composed of gas and dust presumably trapped as the stars formed and held in orbit about the stars; eventually these disks may evolve into planets. The HST images clearly distinguish the central star from the disk and show that stars in Orion that have the mass of our Sun (or a lower mass) are less likely to have disks that could become planets; stars hotter than the Sun might destroy the disks before they can agglomerate into planets, according to O'Dell.

The HST also played a part in observing the July 1994 collision of Comet Shoemaker/Levy-9 with Jupiter, an event of particular scientific significance because it was the first predicted impact of a comet or asteroid with a planet in the recorded history of the solar system. To study the multiple impacts, NASA mobilized its fleet of imaging spacecraft in orbit, including the HST, Jupiter-bound Galileo, the 16-year-old International Ultraviolet Explorer, the Extreme Ultraviolet Explorer and Voyager 2, watching from the edge of the solar system.

These spacecraft, along with NASA's Kuiper Airborne Observatory, a telescope-equipped C-141 transport plane, provided many useful images of the collisions over a six-day period (July 16 - 22) when more than a score of fragments of the broken-up comet plunged into Jupiter. All of the impacts occurred on the far side of Jupiter, not visible from Earth, but soon after each collision Jupiter's rapid rotation swung the post-impact results into view. A typical result: the crash of Fragment G, one of the largest of the comet pieces, generated an immense gas plume some 5,000 miles wide and about 1,500 miles high; astronomers estimated its impact force at six million megatons of TNT, or 100,000 times the power of the largest nuclear bomb ever exploded on Earth.



**Above** is an HST image showing several impact sites, the dark smudges in the lower part of the scene. The smallest of the seven impact features, barely visible, measure almost 200 kilometers across. The lowermost dark blur represents a double impact where Fragments D and G landed relatively close to each other.

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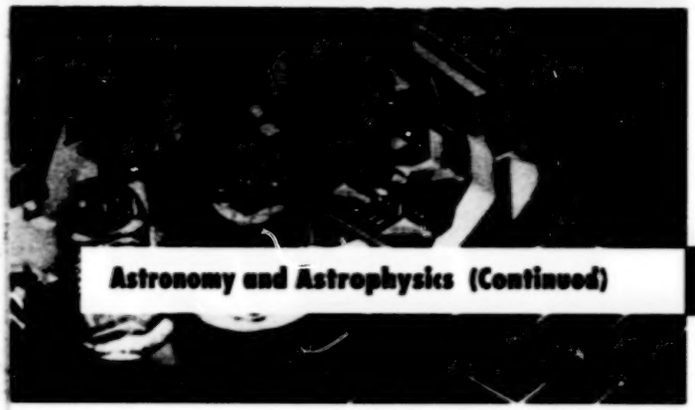
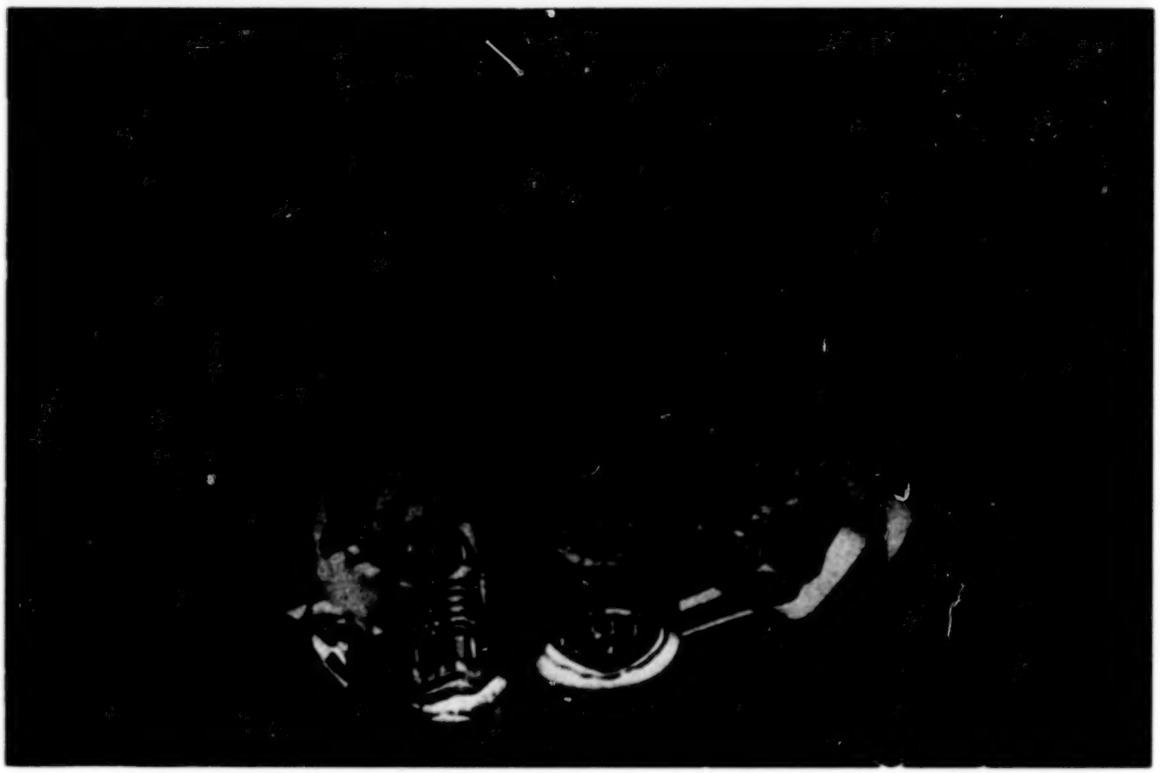






The Hubble Space Telescope (see page 20) is the first of a series of spacecraft known as the Great Observatories, each of which is designed to operate in a certain range of the electromagnetic spectrum, including the full ultraviolet, infrared, x-ray and gamma ray ranges along with visible light. This capability is important to astronomical science because each band of the spectrum offers a different set of clues to the origin and evolution of the universe.

The second of the Great Observatories is the Compton Gamma Ray Observatory **(above)**. Launched in April 1991 and managed by Goddard Space Flight Center, the Compton Observatory is investigating the most energetic of all forms of radiation. Like the HST, Compton has been regularly making new discoveries, such as the 1993 finding that gamma ray bursts, enormous explosions whose sources are one of the great mysteries of astronomy, may be far more energetic than previously thought and may originate far beyond the Milky Way Galaxy (some had thought they occurred only within the Milky Way).

In January 1994, NASA announced that Compton data showed new evidence that gamma ray bursts can occur in the far reaches of the universe and that the bursts show relative "time dilation." This is an effect that would be created by many of the bursts occurring so far away in the universe that time is seen to be running slower there. A NASA team of astrophysicists uncovered the gamma ray burst time dilation by analyzing data from the Burst and Transient Source Experiment (BATSE), a Compton instrument developed by Marshall Space Flight Center.

While Compton's principal work involves viewing distant space, the observatory also conducts Earth observations, and in April 1994 it discovered unusual gamma ray flashes in Earth's upper atmosphere. Described as "a complete surprise to astronomers," these high energy bursts had never before been seen in Earth's atmosphere. The flashes, detected by Marshall's BATSE instrument, were very brief, last only a few thousandths of a second, although some of them consisted of multiple pulses.

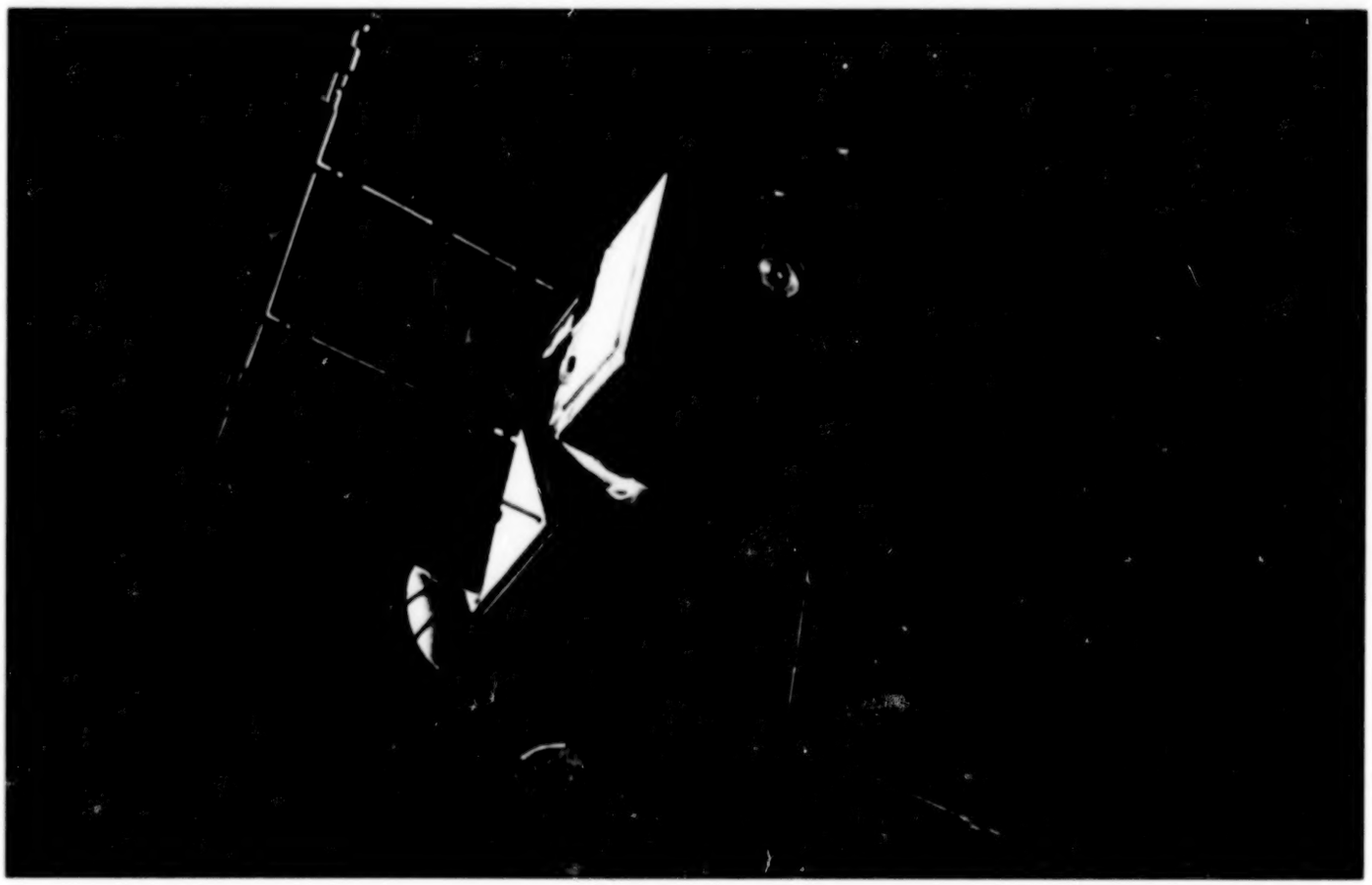
Dr. Gerald Fishman of Marshall's Space Sciences Laboratory reported in a scientific journal that "it is suspected that these flashes come from a rare type of powerful electrical discharge, similar to lightning, above large

thunderstorm regions...It is becoming apparent that the upper atmosphere is much more electrically active than we ever suspected."

In addition to Compton and the HST, NASA astronomical observatories active in 1994 included the Extreme Ultraviolet Explorer (EUVE) shown **below**, which is exploring a wavelength band (EUV) between the ultraviolet and x-ray ranges and cataloging EUV sources; the venerable (launched 1978) International Ultraviolet Explorer, a joint project with the European Space Agency, the United Kingdom and Spain for conducting ultraviolet investigations of stars and galaxies; and the U.S./Germany ROSAT (Roentgen Satellite), which is mapping x-ray emissions from galactic sources.

In development is the third of the Great Observatories series, the Advanced X-ray Astrophysics Facility (AXAF), which will carry instruments many times more sensitive than those of the best prior orbiting x-ray investigators. Originally conceived as one large spacecraft to be used for both x-ray imaging and spectroscopy, the AXAF program was restructured into two separate, lower cost projects. The spectroscopy function was removed from the AXAF spacecraft design, but development of the x-ray spectrometer was continued; NASA is exploring a cooperative mission with Japan that would permit flight of the instrument aboard Japan's ASTRO-E spacecraft.

The AXAF imaging mission -- known as a AXAF-I -- offers comparable science capability than the original AXAF mission with improved observing efficiency. Composed of four grazing incidence x-ray mirrors and two instruments, it will operate in high Earth orbit. In 1998 it will be delivered to low Earth orbit by the Space Shuttle, then boosted by an upper stage to a higher orbit. The AXAF program is managed by Marshall Space Flight Center; TRW Inc. is the principal contractor.



# Mission To Planet Earth

Space Science

Earth is the most complicated planet in the solar system. It is the only planet with oceans and life, and the interactions among living organisms, the oceans, the land and ice surfaces and the atmosphere produce a complex set of mechanisms that control Earth's behavior. Greater understanding of these mechanisms is vital, because the globe is changing and the consequences of change could have serious implications for human health, the world's food and energy supplies, and the global economy.

The urgent need for greater knowledge about Earth's basic processes has resulted in a coordinated international research program to reduce the uncertainties of global change. The United States has established the multiagency U.S. Global Change Research Program. NASA's part of the program is the Mission To Planet Earth (MTPE), a space science effort recently elevated to status as a separate NASA program office.

MTPE has multiple goals: to understand Earth as an integrated system, to gain comprehensive knowledge of the interactions among the planet's mechanisms, to learn exactly how the planet is changing and the extent to which human activities are contributing to change, to assess the potential consequences of change, and to provide the knowledge base for sound policy decisions about the future of Earth's environment.

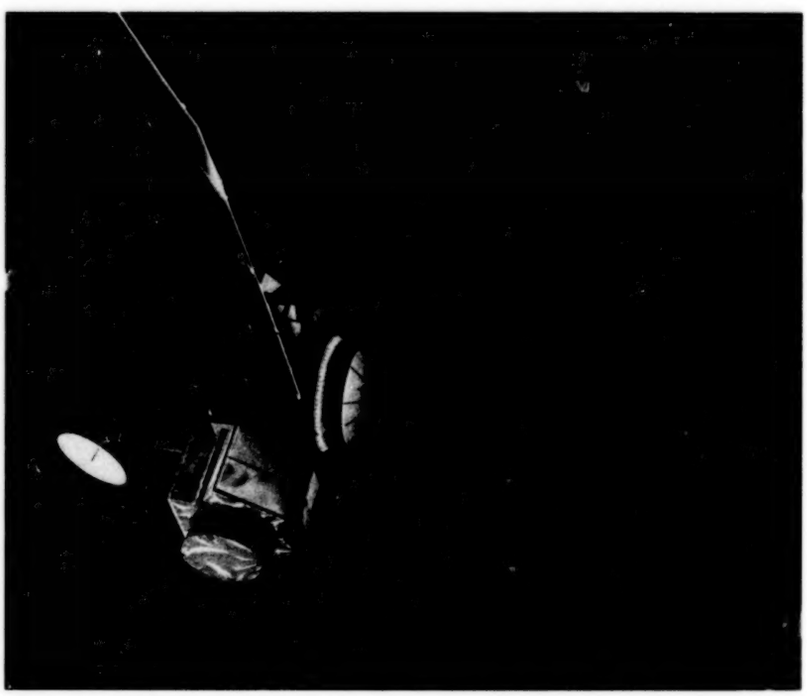
MTPE is a broad program involving research into such areas of environmental concern as ozone depletion, deforestation, climate variability, earthquakes and volcanoes, and the ocean-influenced phenomenon known as El Niño. The research tools include NASA satellites, NASA instruments aboard satellites operated by other U.S. agencies or by foreign nations, Space Shuttle-based instruments, airborne systems and ground-based studies.

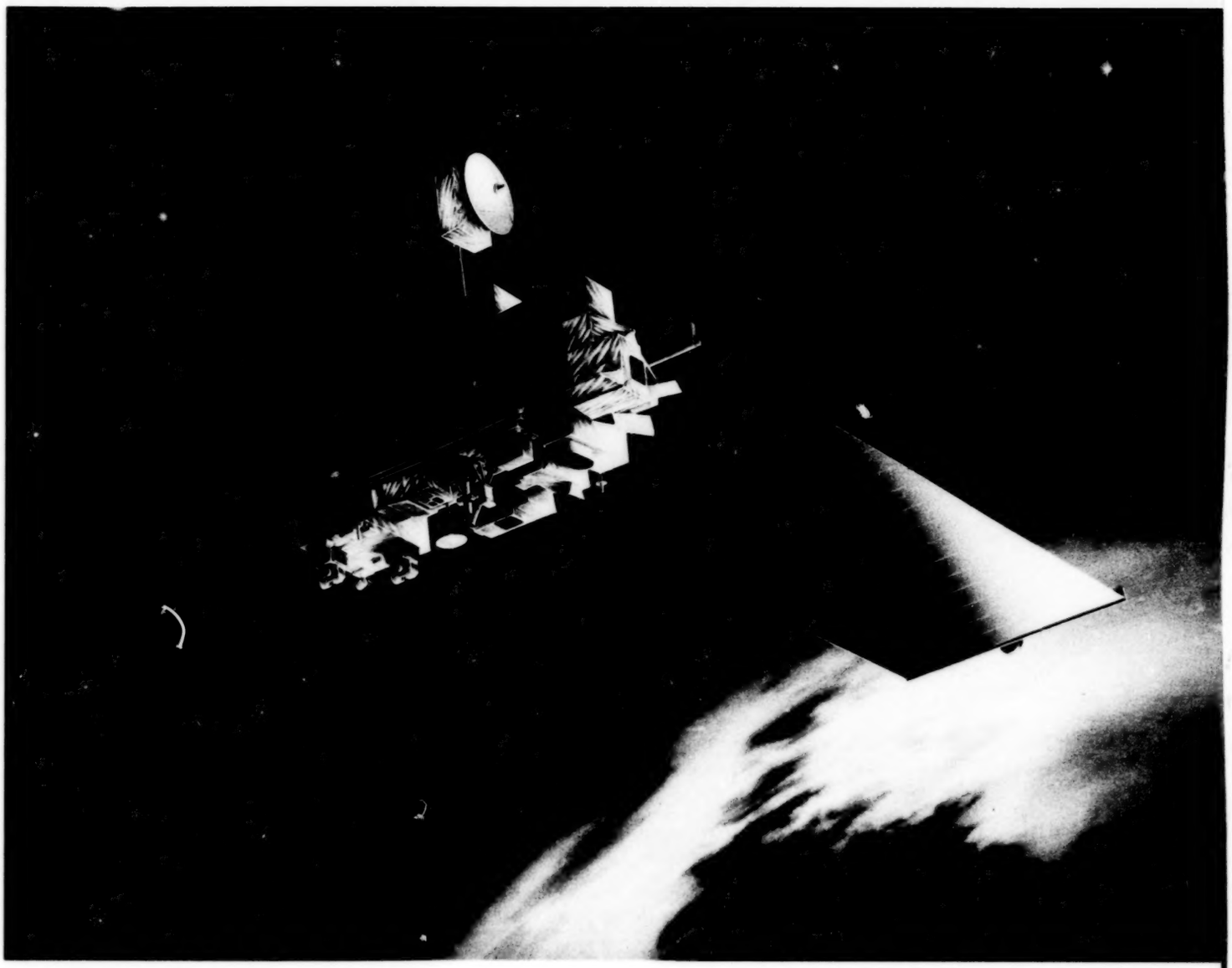
Phase I of the MTPE program has been under way since September 1991. Among major contributors are the Upper Atmosphere Research Satellite, which is investigating the mechanisms that control the variability of the upper atmosphere and the role of the upper atmosphere in climate and climate change; the Shuttle Solar Backscatter Ultraviolet instrument flown annually since 1989 as part of Space Shuttle science missions; the Total Ozone Mapping Spectrometer (TOMS); and the U.S./France Ocean Topography Experiment known as TOPEX/Poseidon.

The TOMS instrument has played a particularly important role in providing the global ozone data on which international agreements to phase out chlorofluorocarbons (CFCs) are based. TOMS began measuring ozone levels in 1978 aboard the Nimbus-7 spacecraft, which ceased operations in 1993. A second TOMS is operating on the Russian Meteor-3 satellite that has been in orbit since August 1991. Another, TOMS-EP94, is aboard a NASA satellite known as Earth Probe, which was awaiting launch at publication time.

Two additional TOMS instruments have been developed for future flights. The fourth TOMS is scheduled for orbital service aboard the Japanese ADECS spacecraft in 1996; the fifth is planned for a flight of opportunity on an international spacecraft. With a design life of two years, the TOMS instruments are expected to provide daily, global total ozone measurements through 2000.

TOPEX/Poseidon, **below** produced the first map of ocean topography in 1993. The satellite addresses how





ocean circulation influences global climate; by mapping the circulation of the world's oceans over several years, TOPEX/Poseidon will help scientists better understand how oceans transport heat, influence the atmosphere and affect climate. A climate-affecting event is the El Niño in which -- at intervals averaging 3-5 years -- the usually cool waters of the Pacific Ocean become warmer; that causes a wide range of effects, including harsher, wetter winters in North America. In November 1993, scientists used TOPEX/Poseidon data to identify a pulse of warm water in mid-Pacific and track its progress toward the South American coast. The data suggests that El Niño may have contributed to the severe winter of 1993-94 and may also have played a part in the 1994 floods in the Midwest and the torrential rains with massive mud slides in California. The NASA portion of the TOPEX/Poseidon program is managed by Jet Propulsion Laboratory.

Phase II of the MTPE program will begin in 1998 with the launch of the first in a series of Earth Observing System (EOS) spacecraft, EOS AM-1 **above**. Where in Phase I measurements focus on fairly specific aspects of the global environment, Phase II will enable the first long-term comprehensive measurements of how the components of the Earth system interact.

The centerpiece of the MTPE program, EOS will involve flights of a diverse set of instruments on a number of spacecraft over a 15-year period. Each spacecraft will focus on a different aspect of global climate change and the interrelation among the components of Earth's environment. EOS data, along with data from airborne and ground-based observations, will enable scientists to model Earth as a global system and to project how human activities will affect the planet.

# International Space Station

Development of the 16-nation International Space Station highlights human space flight activities

On March 23, 1994, the International Space Station program passed a major milestone with completion of the System Design Review at Johnson Space Center. Program managers reviewed and evaluated the overall configuration, technical requirements and detailed specifications for the space station, and they confirmed the validity of the design, the specifications and the operations concept.

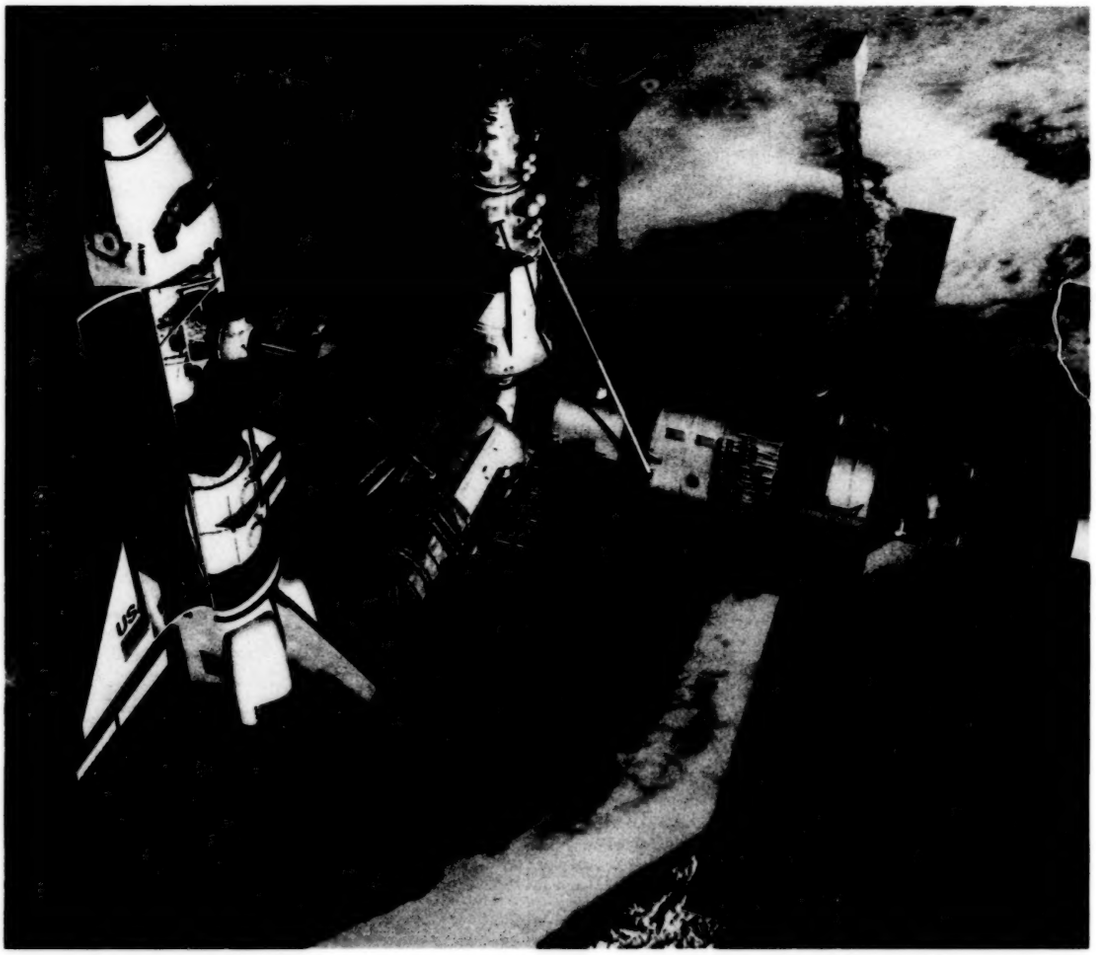
The newest station partner — the Russian Space Agency — participated in the review, along with representatives of NASA, the European Space Agency (ESA), the Canadian Space Agency, the Italian Space Agency, prime contractor Boeing Defense and Space Group, and Tier I subcontractors McDonnell Douglas Corporation and Rocketdyne Division of Rockwell International.

Using approximately 75 percent of the hardware intended for the canceled Space Station *Freedom*, the International Space Station will consist principally of an integrated truss, solar arrays, a habitation module and a laboratory module built by the U.S.; Russian-developed laboratory facilities, a science power platform, a service module and the propulsion/utility module known as the FGB; the ESA laboratory module; the Japanese experiment module and a related exposed facility for "outside" experiments; and the Canadian remote manipulator system.

The addition of the Russian Space Agency to the team permits shaving months from earlier schedules, moving the first assembly launch forward by 10 months and the permanent human capability stage by 15 months. Among the significant changes occasioned by Russia's participation, the space station's orbital inclination will be 51.6 degrees instead of the 28.8 degrees contemplated in earlier concepts; the new inclination offers better Earth observation opportunities, with 85 percent of the Earth's surface observable. Additionally, the station's available power will increase from 68 to 110 kilowatts and the crew size of the permanently manned station will increase from four to six.

Phase I of the International Space Station development program formally started on February 3, 1994, when a Russian cosmonaut flew aboard the eight-day Space Shuttle flight STS-60 (see page 32). This marked the start of a series of cooperative U.S./Russia missions involving cosmonaut flights in the Shuttle and reciprocal flights of American astronauts aboard the Russian space station *Mir*, to be followed by joint Shuttle/*Mir* operations.

Phase I will include seven Shuttle/*Mir* flights, intended to provide joint flight experience to reduce the risks associated with space station assembly and to allow extensive scientific research. The flights, involving tasks ranging from docking and crew exchanges to technical/scientific upgrading of the *Mir* spacecraft, are scheduled between May 1995 and June 1997.



*An artist's conception of STS-71/Mir Expedition 18 in June 1995, a cooperative U.S./Russian mission involving joint training to reduce the risks associated with assembly of the International Space Station. The Shuttle Orbiter pictured is Atlantis; it is linked to the Kristall module of the six-segment Mir by means of a Russian-developed docking system and a U.S.-developed external airlock.*

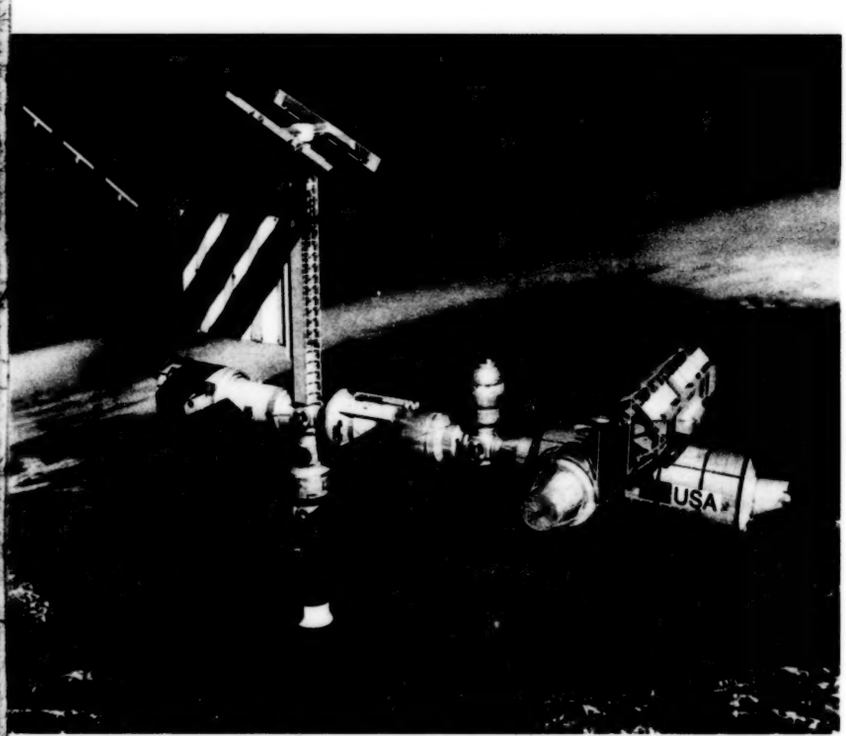
Phase II, the assembly of the initial human-tended capability configuration of the station, will begin in mid-1997. The first station component to be launched will be the FGB "functional control block," which will provide propulsion, electrical power and other services needed during the assembly process.

In all, it will take 35 flights over a 56-month period — 20 by the U.S., 14 by the Russian Space Agency, and one by ESA — to deliver and assemble all the elements of the International Space Station. The target date for completion of the facility and permanent human capability is 2002.

## International Space Station (Continued)

Twelve months into the assembly phase, after eight prior flights for delivery of initial station elements, the U.S. laboratory module will be joined to the growing orbital complex. At that point, about November 1998, the station will have electrical power, life support equipment and microgravity research facilities, allowing "human-tending capability" for a crew of three.

When permanent human capability is attained in 2002, the completed International Space Station will measure 361 feet from tip to tip of the solar arrays at either end; that corresponds roughly to the length of a football field including both end zones. However, the area covered by the station complex is equivalent to that of *two* football fields.




*An artist's concept of the Phase II human-tended Space Station configuration of U.S. and Russian Modules.*

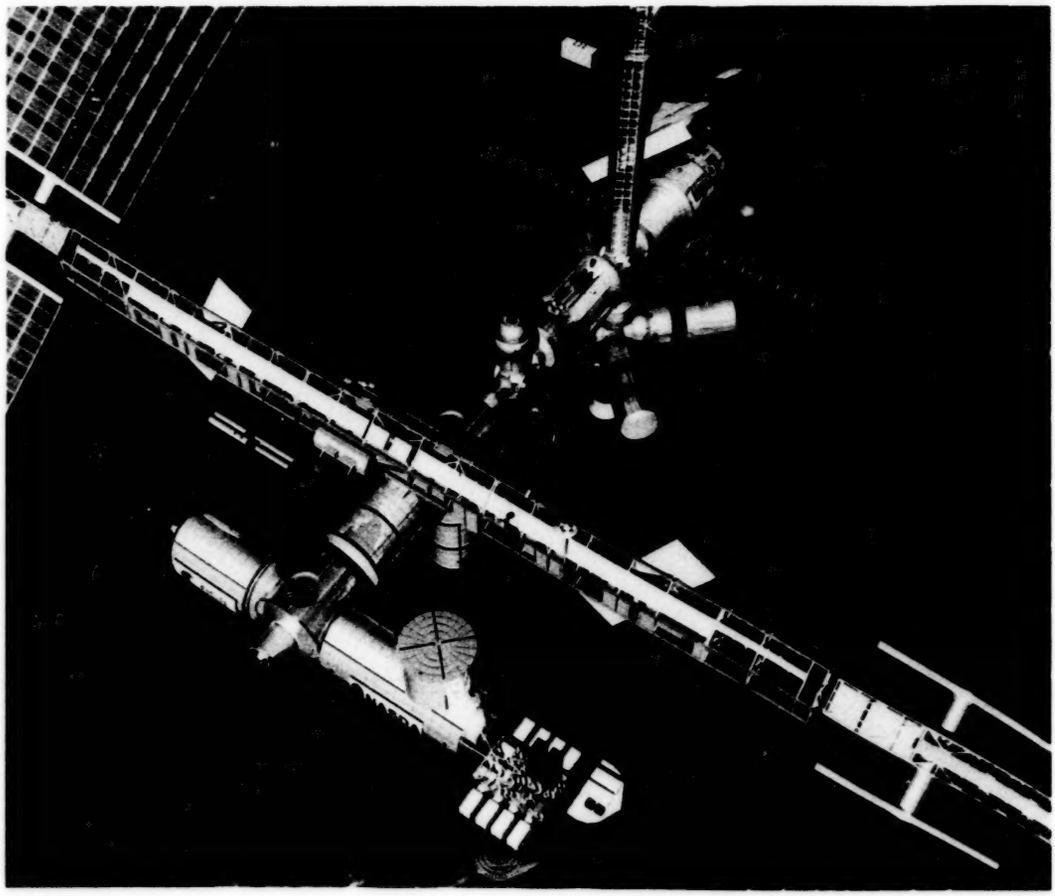
A concept of the Phase III permanent human capability station is shown **at right**. In the foreground are the U.S., European Space Agency and Japanese laboratory modules and the Japanese exposed research facility. Not visible in this view, but located directly below the U.S. laboratory module (conical extension), is the Italian pressurized logistics module. Partially visible below the Integrated Truss is the vertically-mounted U.S.-built habitation module. Beyond the truss are the Russian systems, including three small research modules, the service module, the resupply module, the FGB tug, two crew return vehicles and a power mast with a separate solar array. The main solar arrays extending outward from the truss are U.S.-provided equipment.

The station will operate at an altitude of approximately 240 nautical miles. At that altitude, minute drag forces will cause the station to lose height gradually, so it will be necessary to reboost it every 90 days throughout its lifetime. The reboosting will be accomplished by the FGB.

When the station becomes operational, crews will serve onboard in six month increments. Crew replacement, together with delivery of fuel and supplies, will be handled by the Space Shuttle, the Russian Soyuz spacecraft and the Russian-built resupply module. For emergency departures, the station will have two Soyuz Assured Crew Return Vehicles.

The fully operational station will include a habitation module, supplied by the U.S., and six laboratory modules, provided by the U.S., the European Space Agency, Japan and Russia (three). Oriented to take maximum advantage of the microgravity environment, the laboratory and habitation modules are held in fixed position with respect to Earth's surface; the solar power arrays rotate on the station's Integrated Truss, maximizing their exposure to the Sun without moving the core modules.

The habitation and laboratory modules, along with two pressurized logistics modules, provide a total of 42,443 cubic feet of pressurized volume. That represents 85 percent more pressurized living and working space than would have



*The Phase III version of the station (permanent human capability) will be operational in 2002. It offers living and working space roughly equivalent to the passenger cabin volume of two 747 jetliners.*

been available in Space Station *Freedom*. The size of the orbital laboratory is underlined by this fact: the available pressurized volume is almost equal to that of the passenger cabins of two Boeing 747 jetliners.

The International Space Station offers a facility to perform research investigations that can be carried out in no other way. It enables continuous research in the microgravity environment for years, rather than days, and the presence of a human laboratory staff enables real time changes to experiments, plus the flexibility to do trial-and-error work.

Much of the science and technology development contemplated focuses on gaining better understanding of the most basic mechanics of life and matter; such understanding is expected to create a foundation for a broad spectrum of practical applications, for example, treatments for diseases; improved knowledge of fire propagation for enhanced fire safety; better weather prediction methods; new and dramatically improved materials; development of defect-free castings for such structures as aircraft, bridges, and buildings; better waste management and disposal; improved air and water quality sensors; major advances in computer technology; robotics advancement; and improved resources management.

More than 13,000 NASA and industry employees are engaged in development and construction of the International Space Station; there are more than 500 industry subcontractors and suppliers in 37 states. Industry responsibilities are broken down into three product groups. McDonnell Douglas has responsibility for Product Group One, which includes the station's truss, external thermal control systems, command and data handling, communications and tracking, node/cupola integration, the pressurized mating adapter; guidance, navigation and control. Rocketdyne coordinates Product Group Two: solar arrays, batteries, power distribution and management. Boeing, in addition to serving as prime integration contractor, has Product Group Three: the U.S. habitation and laboratory modules, node/cupola primary structure, life support systems, international thermal control, internal audio/video and the secondary power subsystem.

# Space Shuttle Operations

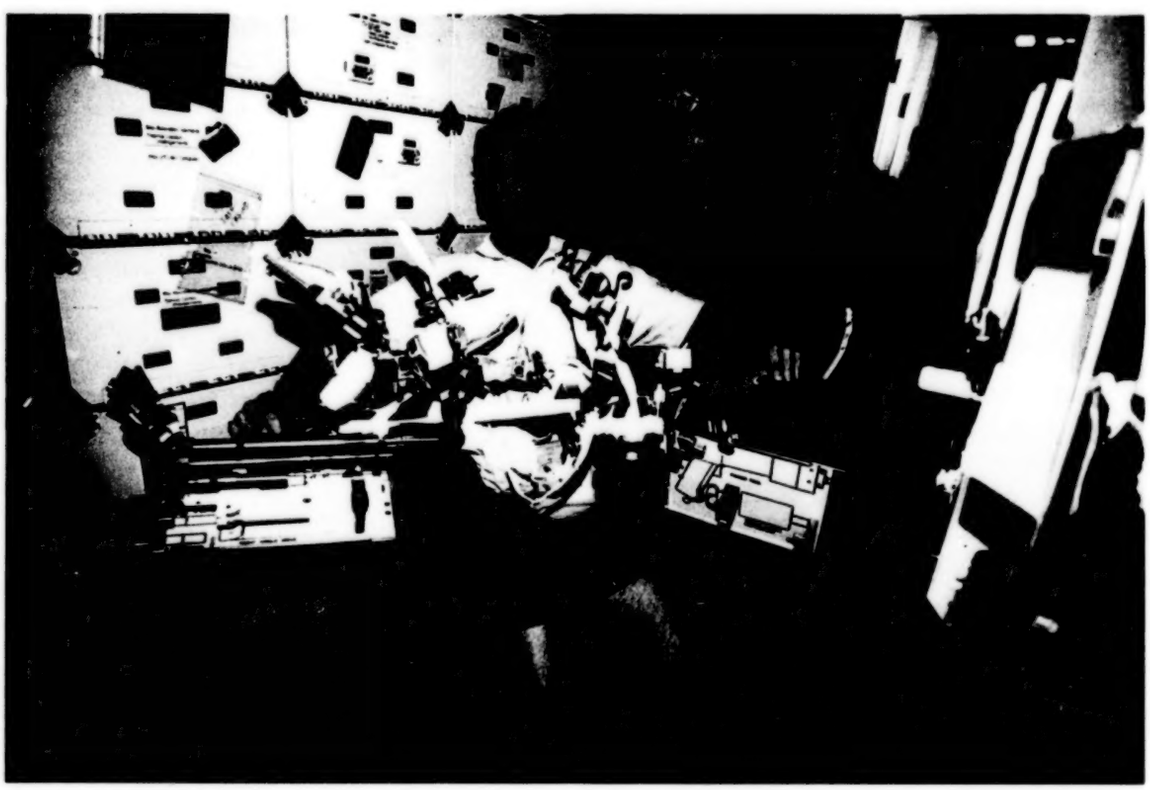


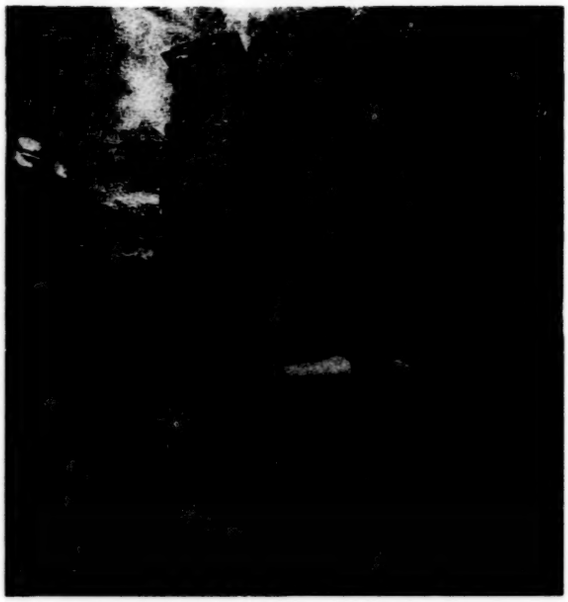
"A shining moment for the space program," one publication called the STS-61 mission that successfully accomplished servicing and correction of the flawed optics of the Hubble Space Telescope (HST). Watched by millions on live television, the mission was flown over an 11-day period December 2 - 13, 1993.

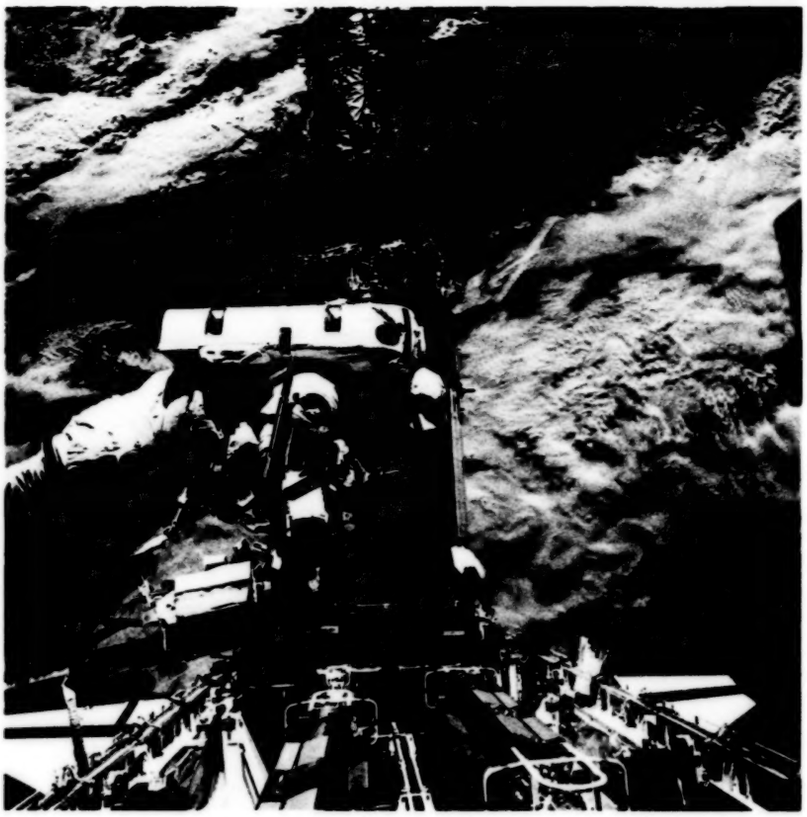
The flight plan called for maneuvering the Orbiter *Endeavour* to a rendezvous with the HST, grappling the telescope with the Shuttle's manipulator arm, securing it in the cargo bay and carrying out a lengthy agenda of servicing and correction operations requiring a record five spacewalks and some 30 hours of extravehicular activity by two pairs of astronauts. Among the major objectives were installation of the Corrective Optics Space Telescope Axial Replacement (COSTAR), designed to remedy the blurred vision of three HST observing instruments, and the installation of the Wide Field/Planetary Camera II, a replacement system that has its own corrective optics.

Additionally, it was necessary to replace Hubble's solar arrays, because it was believed that solar array "jitter" (excessive flexing when the telescope passed from cold darkness into warm daylight) was compromising the structural integrity of the arrays and threatening complete loss of power. Other major objectives including installation of two pairs of gyroscopes, used to point and track the HST, replacement of two electronic control units; and replacement of two magnetic sensing systems, or magnetometers, which measure the HST's relative orientation with respect to Earth's magnetic field.

All objectives were accomplished and subsequent operational use of the HST confirmed that the full science capabilities of the HST had been restored, and that the spacecraft's reliability had similarly been restored by replacement of the solar arrays. STS-61 clearly demonstrated that on-orbit servicing of large observatories like the Hubble is viable.

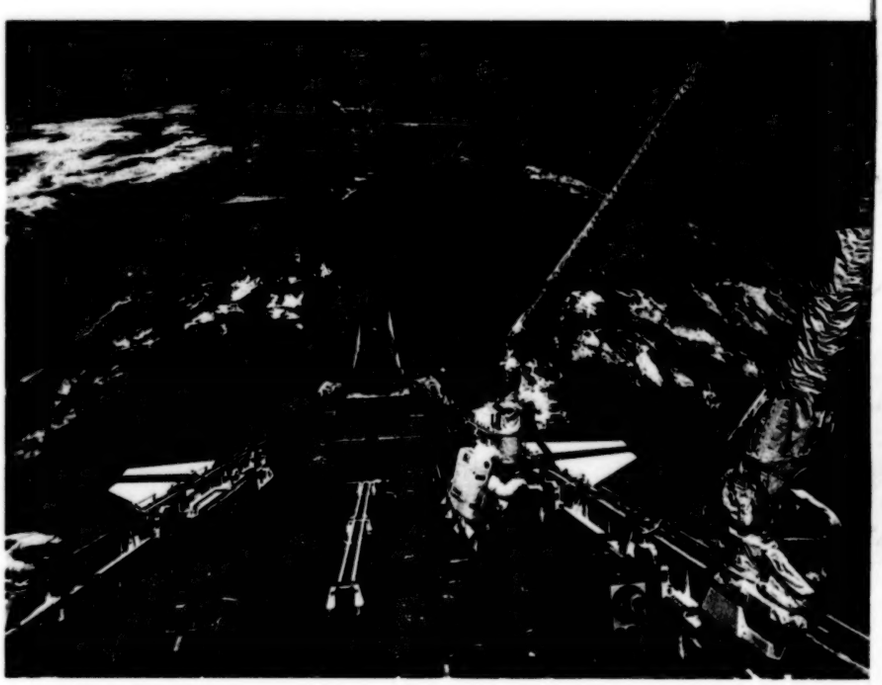






The accompanying photos show the seven-astronaut crew at work. **At far left,** three members of STS-61 are preparing protective anticontamination covers to be placed over the magnetometers being installed; left to right are mission commander Richard O. Covey, pilot Kenneth D. Bowersox and mission specialist Claude Nicollier, a Swiss-born European Space Agency astronaut. **At left**, mission specialist Jeffrey A. Hoffman displays some of the tools to be used on the five spacewalks; STS-61 carried more than 200 tools and crew aids ranging from a simple screwdriver to sophisticated, battery-operated power equipment.

**Above**, mission specialist F. Story Musgrave, anchored on the end of *Endeavour's* Remote Manipulator Systems (RMS), prepares to be elevated to the top of the HST to install the protective covers on the magnetometers. **At top right**, mission specialist Kathryn C. Thornton, gripped by the RMS, is pictured during the changeout of the solar panels, which she accomplished with mission specialist Thomas D. Akers. **At right** is a dramatic view of the restored HST against a blue Earth background; Musgrave, winding up his third spacewalk of the mission, is seen at left center.





The first Shuttle mission of 1994 — STS-60, Orbiter *Discovery* — was launched February 4 on an eight-day flight that included the initial test of the Wake Shield Facility (WSF), a 12-foot-diameter steel disc designed to generate an "ultravacuum" in space for experimental growing of thin semiconductor films to be used in next-generation electronics.

According to the research plan, the WSF was to be released from the Shuttle to operate for a time in free flight and then to be retrieved. A sensor malfunction, however, barred release of the satellite. The WSF was able to operate while connected to the Shuttle's manipulator arm and a test quantity of semiconducting material was produced for NASA/industry analysis. Developed by the Space Vacuum Epitaxy Center at the University of Houston, Texas, the WSF is scheduled for its second flight in the spring of 1995.

STS-60 was also notable for the presence among the crew of Russian cosmonaut Sergei Krikalev, a veteran of two long-duration stays aboard the MIR space station. Krikalev's Shuttle flight marked the start of a series of cooperative U.S./Russia missions preliminary to Russian participation in the International Space Station program. **At left**, Krikalev is explaining on-board activity to students in Maine, using the SAREX II (Shuttle Amateur Radio Equipment-II) system; as part of a continuing NASA educational effort, crew members used SAREX to lecture American and Russian students about STS-60 mission objectives and what it is like to live and work in space.

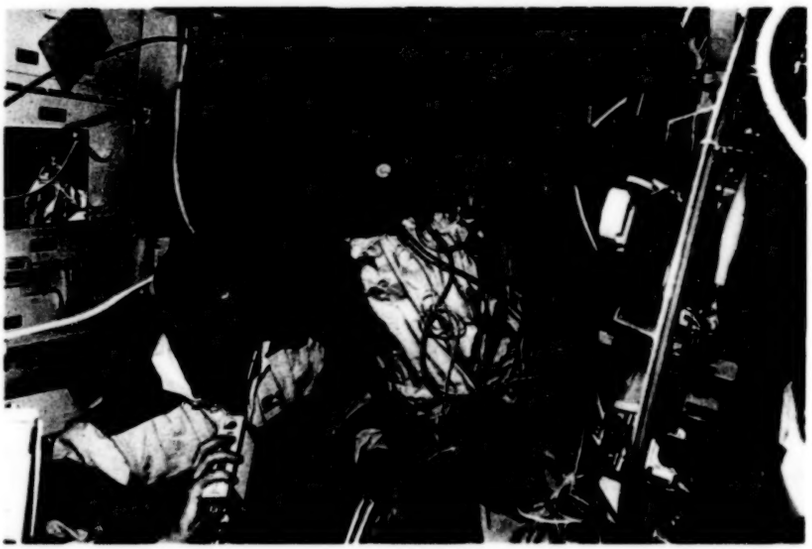
STS-60 marked the second flight of SPACEHAB, a pressurized facility that rides in the Orbiter's cargo bay and makes available additional space for crew-tended payloads. Developed by SPACEHAB, Inc., Arlington, Virginia, SPACEHAB can accommodate up to 61 experiment lockers, each with two cubic feet of volume; the company leases locker space and experiment related services on a commercial basis. SPACEHAB-2 carried more than two dozen experiments involving materials processing, biotechnology and hardware/technology development payloads. **Above**, mission specialists Ronald Sega (foreground) and Jan Davis are stowing experiments and gear after several days testing in the SPACEHAB module.

On March 4, 1994, NASA launched STS-62, Orbiter *Columbia*, on a 14-day flight with an exceptionally broad range of experiment objectives, most of them concerned with the effects of microgravity on organisms and materials. Among the array of investigations were studies that assessed the impact of long-duration weightlessness on astronaut health; a study of the complex relationship between the immune and skeletal systems during exposure to microgravity; tests of a temperature control device designed for use with the Bioreactor, a cell culture growth system; operation of a Fluids Processing Apparatus that supported 15 commercial life science

investigations toward applications in biomaterials, biotechnology, medicine and agriculture; and further crystal growth studies to help scientists understand the complex molecular structures of important proteins.

The principal cargo bay payload of STS-62 was the U.S. Microgravity Payload-2, a facility for fundamental science experiments that cannot be conducted on Earth. On USMP-2, two experiments focused on studies that could lead to better, faster semiconductors. Another studied the critical point where a fluid is simultaneously a gas and a liquid, research for gathering information on a fundamental physics theory that has broad potential for Earth applications. USMP-2 also studied the formation of dendrites, which can determine the strength and durability of steel, aluminum and superalloys used in production of automotive and aircraft components.

**Above**, mission specialists Pierre J. Thuot (top) and Sam Gemar dispiay the Middeck O-gravity Dynamics Experiment (MODE), which is designed to enable study of the behavior in microgravity of structures and contained fluids planned for future spacecraft. **Below**, Gemar (left) is assisting STS-62 pilot Andrew M. Allen in a "soak" test that employs a fabric bag to lower the pressure around the lower body, a measure intended to prepare a spacefarer for the return to Earth gravity conditions. In the **bottom** photo, Gemar (left) and mission commander John H. Caspar are conducting environment-related Earth observations.





On April 4, 1994, NASA launched STS-59, Orbiter *Endeavour*, on an 11-day mission featuring investigations by the Space Radar Laboratory-1 (SRL-1), part of the Mission To Planet Earth program that seeks broader knowledge of how Earth's environment is changing.

To be flown repetitively, the SRL has two elements: a suite of radar instruments called SIR-C/X-SAR, which stands for Space Imaging Radar-C and X-Band Synthetic Aperture Radar, and an atmosphere monitoring instrument known as MAPS (Measurement of Air Pollution from Satellites). The SIR-C was built by Jet Propulsion Laboratory and Ball Communications Systems Division; the X-SAR instrument was developed by the Dornier and Alenia Spazio companies for the German Space Agency (DARA) and the Italian Space Agency (ASI). The MAPS hardware was developed by Langley Research Center. The SIR-C/X-SAR systems occupied more than three-quarters of *Endeavour's* cargo bay, MAPS the remainder.

The advanced radars acquired imagery and data from more than 400 Earth sites, including 19 locations designated as "supersites," high priority focal points for many of the scientific investigations. They sought information about how elements of the complex Earth system —particularly land surfaces, water and life — work together to create Earth's environment. Of special interest was data on vegetation coverage, the extent of snow packs, wetland areas, geologic features, volcanic processes, ocean wave heights and wind speeds. The mission produced more than 30 trillion bits of data, the equivalent of 20,000 encyclopedia volumes; it was expected that detailed data processing and development of imagery would take more than a year.

The SIR-C/X-SAR experiments were conducted by an international team of 49 science investigators and three associates representing 13 nations.

The MAPS experiment measured the global distribution of carbon monoxide in the troposphere, or lower atmosphere. Carbon monoxide measurements provide scientists with indications of how the atmosphere can cleanse itself of "greenhouse gases," chemicals that can raise the atmosphere's temperature.

STS-59 was commanded by Sidney M. Gutierrez, shown in the left seat **at left** during a checkout of *Endeavour's* flight control system; mission specialist Michael R. U. (Rich) Clifford is in the center and pilot Kevin P. Clifton at right. **Below**, mission specialist Jerome (Jay) Apt uses a 70-millimeter camera to record

Earth scenes. **Above**, mission specialist Linda Godwin lectures students listening in at Earth schools, part of the continuing series of SAREX educational experiments (see page 32). **At right**, mission specialist Thomas D. Jones, anchored to a bunk, displays a novel workstation for the weightless astronaut.

The second flight of the International Microgravity Laboratory (IML-2) began with the launch of STS-65, Orbiter *Columbia*, on July 8, 1994. The IML-2 mission configuration consisted of a pressurized Spacelab long module in the cargo bay, connected to the Orbiter mid-deck by an access tunnel. The remainder of the cargo bay area was occupied by an EDO (Extended Duration Orbiter) pallet containing extra oxygen, hydrogen and other supplies for a planned two-week mission.

STS-65 astronauts conducted approximately 80 experiments developed by 13 different countries in IML-2, with emphasis on investigations of the effects of microgravity on living organisms fluids and materials. Life science experiments were aimed at providing scientific data on the role of gravity in shaping life and how organisms adapt to the weightless environment. Microgravity science experiments sought insight on fluid and materials properties and processes that are difficult to characterize on Earth.

Among secondary mission objectives, STS-65 carried measuring systems for acquiring data on the microgravity environment itself for calibrating experiment results. The ongoing Extended Duration Orbiter Medical Program, aimed at protecting crew health and safety on future missions, assessed the medical status of the crew throughout the mission. At 15 days the longest shuttle flight, STS-65 was jointly sponsored by NASA, the European Space Agency, the German Space Agency, the Canadian Space Agency, the French Space Agency and Japan's National Space Development Agency.

# Technology Twice Used

*A representative selection of new products and processes adapted from technology originally developed for NASA mainline programs, underlining the broad diversity of spinoff applications and the social/economic benefits they provide*

Spinoff developments highlighted in this publication are based on information provided by secondary users of aerospace technology, individuals and manufacturing concerns who acknowledge that aerospace technology contributed wholly or in part to development of the product or process described. Publication herein does not constitute NASA endorsement of the product or process, nor confirmation of manufacturers' performance claims related to the particular spinoff development.

# A Testing Service For Industry

A little known NASA facility is making a significant contribution to national safety and industrial productivity

In the shadow of the San Andres Mountains of south central New Mexico, there is a relatively small, isolated NASA facility whose capabilities are unique in the United States, perhaps anywhere. Little known to the general public, White Sands Test Facility (WSTF) has established a world class reputation among the government/industry technical community for its expertise in the broad field of flammability and fire hazard testing and the more specific area of improving safety in materials and equipment used in oxygen systems.

A subsidiary unit of Johnson Space Center (JSC), NASA's field center for manned space flight development and operations, WSTF is primarily responsible for supporting JSC programs. In recent years, however, the facility has taken on an additional mission: helping industrial firms to design, test and operate oxygen systems with greater safety.

Although the laboratory is not officially a part of NASA's Technology Transfer Network (see page 120), it has nonetheless become a prime source of technological assistance for oxygen system producers and users, providing test data that companies could not otherwise acquire without considerable expense and difficulty, sometimes not at all.

It's a "win-win" situation. Because industry assistance is furnished on a cost-reimbursable basis, NASA is able to provide, at little or no cost to the government, a service that enhances national safety and benefits individual companies in more efficient design and better product performance. Industry gets a bargain, too, because the cost of the WSTF service is typically modest in comparison with what it would take for the company to generate the data on its own.

For example, WSTF conducted tests for General Electric Aircraft Engines, Evendale, Ohio to provide data on the flammability of several advanced alloys being considered for use in gas turbine engines; for $19,000, GE got a wealth of data that was used to establish key guidelines for combustion resistance in the development of new alloys for jet engine compressors. For $52,000, Exxon Research and Engineering Company, Florham Park, New Jersey acquired high temperature combustion test data that allowed selection of the best materials for use in a chemical process being developed.

Sometimes a WSTF service costs nothing at all, such as a consultation on ignition and combustion hazards, or provision of already available technical information. The Linde Division of Praxair, Inc., Tonawanda, New York was provided drawings for a high pressure, NASA-developed combustion test apparatus that enabled the company to build its own test system inexpensively by using a proven design.

There is wide and growing interest in WSTF's service among commercial firms making products that incorporate oxygen systems or operate in oxygen-enriched atmospheres. There are, first of all, the oxygen producers and manufacturers of related equipment, such as tanks and regulators. Among the major oxygen users are the builders of flight vehicles —spacecraft, rocket boosters, military aircraft, jetliners and private aircraft, and such marine craft as sub-

ORIGINAL PAGE
COLOR PHOTOGRAPH

marines and deep submergence vehicles.

There is a great variety of oxygen equipment usage in industrial processing, particularly in the chemical and steel industries, and there is a wide range of institutional and commercial users, from such lifeguarding services as hospital care and firefighting to such outdoor activities as scuba diving and mountain climbing. Additionally, WSTF provides test data not directly related to oxygen systems, for example, flammability data on a great variety of materials tested at various atmospheres and pressures.

WSTF started life in 1962 as a facility for test of rocket propulsion systems, principally for the Apollo lunar landing program. The New Mexico desert site was chosen for its isolated location and topography, which allowed minimal hazard to the general population.

*At New Mexico's White Sands Test Facility, NASA is transferring to industry technology for improving safety in designing and operating oxygen systems. One method of transfer is classroom instruction for industry people; here NASA engineer Joel Stoltzfus (with pointer) and consultant Barry Newton (seated on table) are instructing on fire hazards and safety procedures.*

In 1967 and thereafter, WSTF's role was expanded to give NASA an advanced materials testing capability focusing on oxygen and propellant exposure environments. Initially, the laboratory concentrated on evaluating the flammability and toxicity characteristics of materials used in the Apollo program; later, WSTF expanded its horizons to include research on all facets of materials characterization, compatibility and component verification.

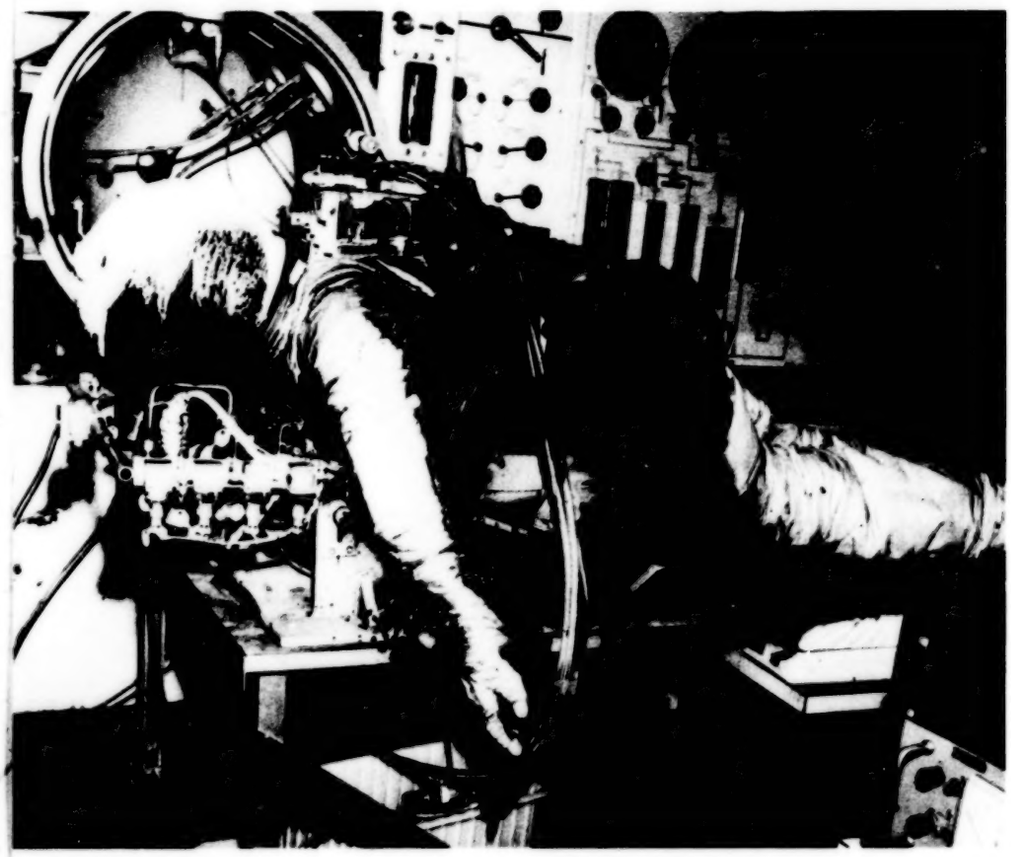
Over the past quarter century, WSTF's scientists and engineers have conducted an extremely comprehensive investigation toward understanding the science governing the ignition and combustion of materials and, in the process, developed an extraordinary degree of expertise in that field. The laboratory won recognition for its unique capability when, beginning in the early 1970s, the American Society for Testing and Materials, which sets standards for the nation, adopted a number of WSTF's materials and components test methods. More recently, WSTF helped develop ASTM's training course *Controlling Fire Hazards in Oxygen-Handling Systems.* The National Fire Protection Association (NFPA) has similarly acknowledged WSTF's expertise; the NASA laboratory provided the majority of the input to NFPA's current *Manual on Fire Hazards in Oxygen-enriched Atmospheres.*

By the end of the 1970s WSTF had become a national resource. As the results of the laboratory's research and testing were published in the open literature, the facility received many requests from members of the oxygen producing and oxygen equipment-using community for more information and advice on how to apply the information. That led — in 1980 — to a NASA authorization that allowed industry to take advantage of the broad expertise and the highly advanced test facilities available at WSTF.

(Continued)

## A Testing Service For Industry (Continued)

Manufacturers of oxygen systems and components often find it difficult to get testing data and hazard analysis for their equipment, information that is important to efficient design and product safety. Some companies simply do not have the facilities needed for advanced, specialized testing. Many companies do have their own facilities, but advancing technology frequently creates a need for testing that is beyond the company's in-house capability. In other cases, the kind of testing needed may be of too hazardous a nature for the company's facilities and expertise.



*An accidental fire in this space suit (unoccupied) triggered a safety improvement. White Sands Test Facility (WSTF) traced the cause to a high pressure regulator made of aluminum, which was replaced by a more burn resistant copper-nickel alloy.*

That's why NASA's decision to make WSTF's facilities available to private companies was a major boon to the oxygen systems industry. Users get the service of a top rank testing complex on a relatively inexpensive, cost-reimbursable basis and they get the test data in a timely fashion. Otherwise, they would have to purchase — or perhaps invent — the testing equipment, set it up in a protected environment and learn how to operate it, adding a lot of time and money to the cost of product development.

One of WSTF's clients is Wendell Hull & Associates (WHA), Las Cruces, New Mexico, a firm that does forensic consulting, failure analysis and accident investigation. For hazardous testing or tests WHA cannot handle in-house, the company concluded an open-end cost-reimbursable arrangement with NASA whereby WSTF does the requisite work.

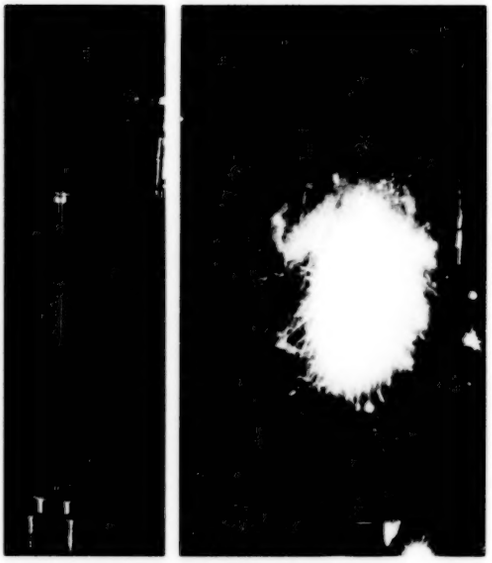
The arrangement has worked to the benefit of both parties. WHA reports that it has been "significantly aided" by WSTF's testing and analysis. WSTF, on the other hand, is now utilizing WHA's services to meet a need for a way of smoothing the path for private companies who find it difficult to get the test data they need. WHA serves as a facilitator, or liaison group, to arrange contract testing at WSTF. As part of its intermediary role, WHA is working with WSTF to cut the time it takes to set up and obtain test data; the cooperative effort has brought a significant reduction and a company can now accomplish some kinds of testing in as little as two weeks.

"The opportunity to utilize the unique facilities and expertise at NASA-WSTF has been a tremendous asset to our own failure analysis efforts," says Barry

Newton of WHA. "The specific capabilities and expertise at WSTF simply do not exist, to our knowledge, anywhere else. Furthermore, we have found that private industry is extremely interested in this mechanism for obtaining cost-effective and timely testing from a one-of-a-kind world class laboratory."

WSTF has received a number of similarly enthusiastic endorsements of its service. And as the word spreads throughout the industrial community, the facility's client list is getting longer; WSTF is now getting up to five requests a week for test data or consultation. The list is already very impressive, containing some of the biggest names in American industry — names like Du Pont, AlliedSignal, Boeing Commercial Airplane Group, Hoffman-LaRoche, Inc., General Dynamics, Phillips Petroleum, TRW Inc., Lockheed Corporation, McDonnell Douglas Corporation, Rockwell International, Kimberly-Clark, General Electric, Exxon, Virginia Power and Electric and Martin Marietta Corporation. These companies all have extensive research facilities and their use of WSTF's services amounts to tacit acknowledgement that the NASA facility offers a first class testing capability and an efficient, cost-effective service.

The WSTF story exemplifies one facet of NASA's broad effort to transfer government-developed technology to the private sector in the interest of improving the productivity and competitiveness of American industry. WSTF's work is of the direct benefit variety of technology transfer wherein NASA develops or applies technology for a specific purpose — developing an advanced communications satellite, for example.



*A flammability test at WSTF: the titanium rod in the left image is ignited and burned in an oxygen-enriched environment and scientists study combustion characteristics. WSTF conducts tests like this to help system designers select the most burn resistant metal alloys for use in oxygen systems.*

The broadest area of NASA technology transfer is the indirect benefit that accrues from "spinoff," the secondary application of technology originally developed to meet the challenging demands of NASA mainline programs. There have literally been tens of thousands of spinoffs. Collectively, they represent a substantial return on the nation's investment in aerospace research. Frequently they spark formation of new companies and thereby create new jobs; they generate lifestyle innovations and solutions to pressing public problems; and they have a stimulating influence on the national technological process, hence make a valuable contribution to the U.S. economy.

The chapters that follow contain a representative sampling of current spinoffs and illustrate how once-developed NASA technology is being reapplied in many ways and many fields of everyday life.

*WSTF performs a wide range of services for its industry clients, among them servicing of parts used on oxygen systems — cleaning, repairing, testing and packaging, all conducted in a high technology clean room environment*

# A Third Arm for the Surgeon

Among spinoffs in the field of health and medicine is a robotic aid to safer surgical procedures

In 1993, laparoscopic surgeons at the University of California San Diego (UCSD) Medical Center conducted trials on human patients of a new medical robot called AESOP, developed by Computer Motion, Inc., Goleta, California with the help of funding and technological assistance from Jet Propulsion Laboratory (JPL). It marked the first time a "robotic assistant" had been used in laparoscopic (minimally invasive) surgery.

AESOP stands for Automated Endoscopic System for Optimal Positioning, which means that AESOP's robotic arm holds, moves and positions a key instrument — the endoscope or laparoscope — for the surgeon in minimally invasive procedures.

Laparoscopy is a surgical method employed in roughly a million operations a year for such procedures as gallbladder removal, hernia repair, gynecological surgery, orthopedic surgery and neurosurgery; its goal is to reduce risk, cost and length of surgery/healing time by reducing the patient's trauma. In such procedures, the surgeon makes only tiny incisions in the patient's body and in one of them inserts the laparoscope, an optical tube with a camera at its end. The camera's image is projected onto two video screens, whose views guide the surgeon through the surgery.

With AESOP, the robotic arm that moves the tube and its camera is controlled by the operating surgeon rather than an assistant. The surgeon uses a foot pedal control to move the device for different views, from an overview of the operating site to a closeup for cutting or suturing. Foot control allows the surgeon use of both hands for the procedure. More importantly, the absence of a separate camera operator eliminates the possibility of miscommunication when the surgeon wants the camera repositioned.

In addition to reduced risk, AESOP offers other advantages, according to Dr. Jonathan Sackier, associate professor of surgery at UCSD and director of clinical studies for AESOP, who says that AESOP "improves the quality of the procedure; it allows the surgeon to directly control the field of vision, its movement is smooth and steady, and the memory vision is invaluable." He estimates that the three operations he personally performed with robot assistance were completed at least 20 percent faster — and at $1,500 an hour for the operating room, that's significant. He points out, too, that less time under anesthesia is better for the patient.

AESOP is the result of Robotic Enhancement Technology (RET), an approach to robotic systems pioneered by Computer Motion, Inc. RET combines the intelligence of the operator and the dexterity of the robot to perform manipulations that neither could manage alone.

Founded in 1989, primarily as a research and development company, Computer Motion has performed contract work for such government agencies as NASA, the National Science Foundation, the National Institutes of Health and the

U.S. Navy, and for such private sector clients as GM Hughes, Allison Gas Turbine and Toyota. In 1991, the company began to apply its research efforts to the commercial marketplace, focusing on development of robotic systems for medical applications.

Computer Motion was helped by technology guidance and funding from JPL, a world leader in robotics. Under the direction of Dr. Neville I. Marzwell, technical manager for robotic systems and advanced computer technology, JPL is engaged in developing a number of semiautonomous systems for assembling space structures and servicing spacecraft. Marzwell's group is increasingly active in promoting the transfer of space technology to industry and JPL works closely with industry firms to adapt NASA technology to industrial applications.

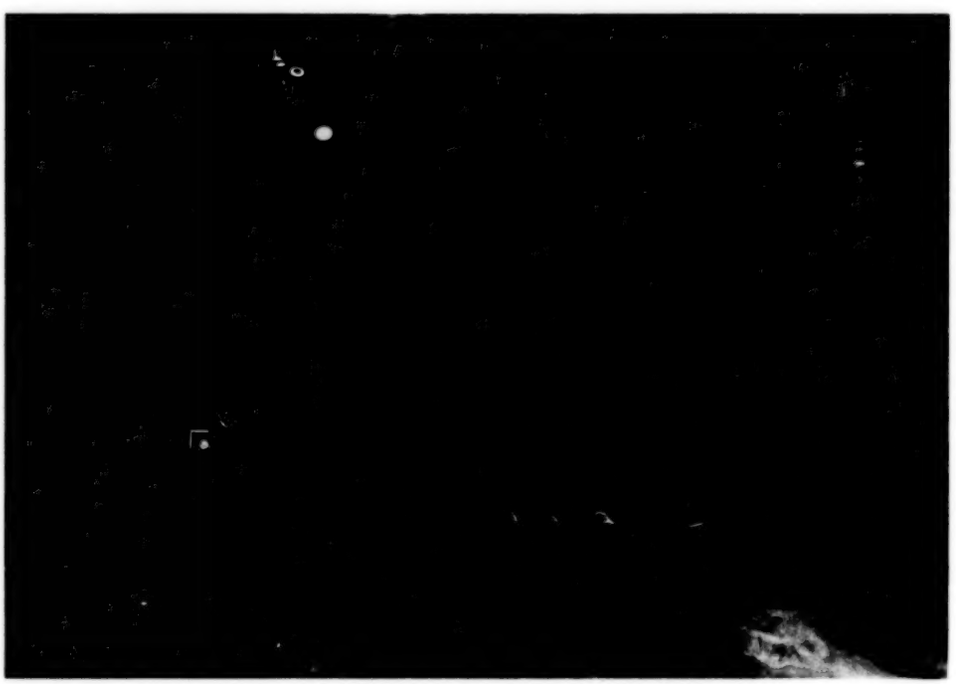
*This photo illustrates the operation of the AESOP robot (foreground) as a surgeon's "third arm" in minimally-invasive surgery. AESOP is holding a tube with a tiny camera at its end in an incision; using a foot controller, surgeon Dr. Jonathan Sackler, director of clinical studies for AESOP, moves the tube and camera for changing views of the operating site. Below is a closeup of the AESOP system, including the robotic arm, a foot controller (left), a hand controller and the control computer.*

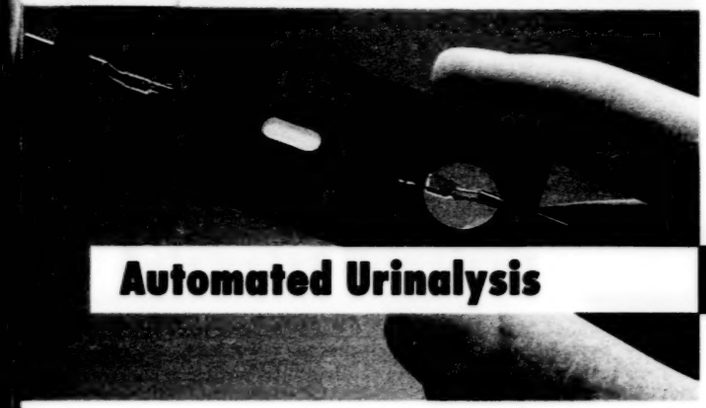
In some instances, such as Computer Motion, JPL is able to award Small Business Innovation Research (SBIR) contracts to help a company commercialize a product.

"Through these relationships," says Marzwell, "we can offer technology and hands-on experience in exchange for a commitment from industry to bring a technology to market."

Dr. Yulun Wang, founder and president of Computer Motion, confirmed that "the NASA funding which we have received through the SBIR program has been highly beneficial to our rapid progress in the development of unique robotic systems."

At midyear 1994, nine other hospitals — in addition to the UCSD Medical Center —had initiated surgical procedures with AESOP and Computer Motion had received Food and Drug Administration approval to begin marketing the system to hospitals nationwide.





# Automated Urinalysis

Health and Medicine

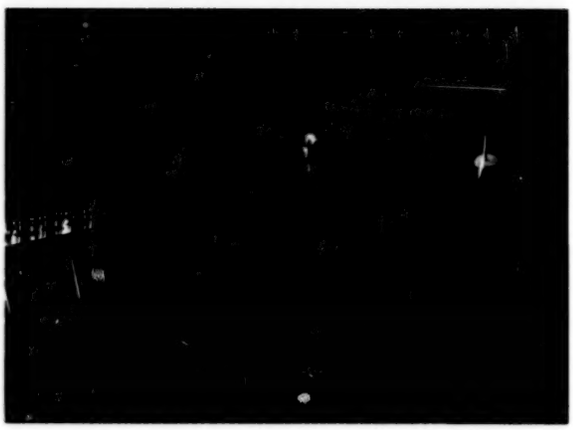
**NASA** *Tech Briefs* is a monthly publication that advises potential users what NASA-developed technologies are available for transfer and serves additionally as a problem-solving tool for its 200,000 industry and government readers (see page 129). Each issue reports on newly developed products and processes, and on innovative technologies originating in NASA research. Readers interested in adapting a particular innovation to their own purposes can get more detailed information from NASA by requesting a Technical Support Package (TSP).

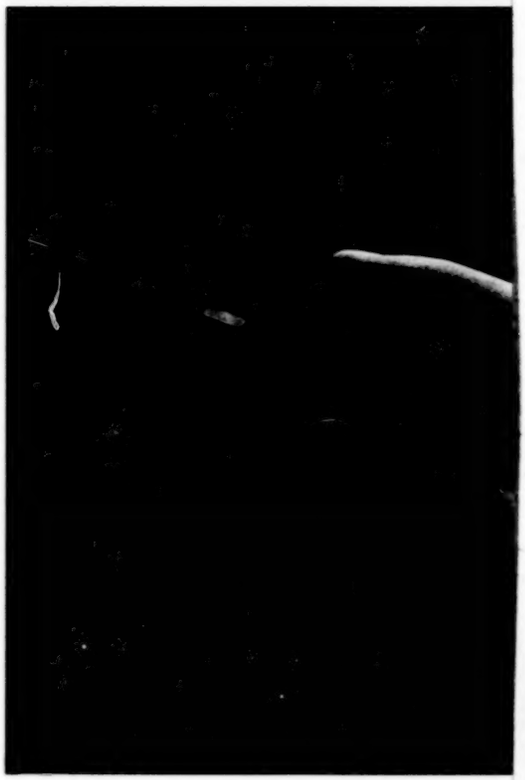
*Tech Briefs* has become a prime source of spinoff applications. Sometimes the information in a *Tech Briefs* article, or a series of articles, is by itself sufficient to generate a spinoff product or to solve a problem related to a new development without need for the TSP. An example is the experience of DiaSys Corporation, Waterbury, Connecticut, which used *Tech Briefs* information to resolve a difficult problem involved in the development of the company's R/S 2000 instrument for automated urinalysis.

Conventional urinalysis is largely a manual process. Generally a sample of urine is poured into a tube and the tube is centrifuged for several minutes, creating a concentration of urine sediment at the bottom of the tube. Using a pipette, a thin plastic tube for transferring fluids, a sample of the sediment is deposited on a glass slide and the slide is topped with a cover slip to make a "glass sandwich." Then the slide is placed on a microscope stage for viewing.

The R/S 2000 automates most of that procedure. An operator — who needs no special training — inserts the R/S 2000's automatic aspirator into a standard tube of urine specimen and presses the "Sample" button. Within three seconds a consistent amount of sediment is automatically transferred to the stage of the microscope, ready for viewing. When observations are completed, the operator presses a "Flush" button and the system is purged; the sample/flush solution is deposited in the specimen tube, from which the urine was initially drawn; the tube is then discarded.

**Below**, DiaSys president Todd M. DeMatteo (standing) discusses the operation of the R/S 2000 with a laboratory pathologist. In the background, product inventor Walter Greenfield confers with a lab technician. **At right** is the complete R/S 2000 system, including the slide





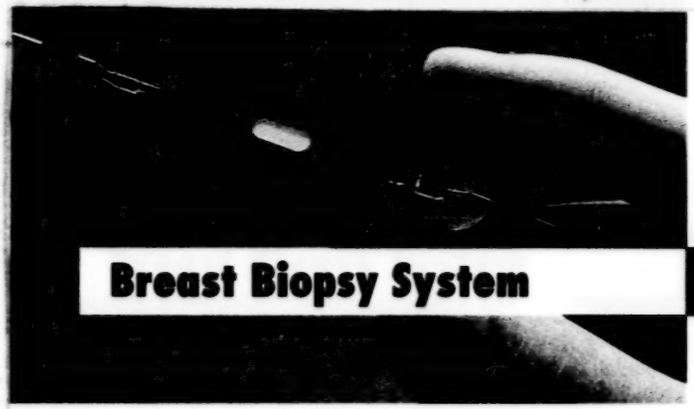
(foreground), the pump unit **(center photo)** and the test tube racks. **At right** is a closeup view of the slide, which fits any microscope. **The lower photo** compares the DiaSys slide (black) with current method equipment, including microscope slide, cover slip and pipettes, all of which must be discarded as "red bag" waste. The instrument, DiaSys officials say, "speeds up, standardizes, automates and makes safer the analysis of urine." It eliminates the use of pipettes, slides and slide cover slips, it improves the accuracy and reproducibility of analysis, and it reduces exposure to potentially infectious materials.

The fluid sample is delivered to the microscope by a peristaltic pump connected by tubing to a proprietary optical slide assembly (OSA) located on the stage of the microscope. In the course of developing the OSA, it became apparent that pumped fluids, under a magnification of 400X, exhibited radically different characteristics from fluids deposited manually on a glass slide by a pipette. In early OSAs, particulate matter tended to collect and bunch up within the cell chamber, obscuring view and rendering the specimens unacceptable. The problem resisted solution through several modifications.

Then Walter Greenfield of DiaSys discovered several pertinent articles in *Tech Briefs*, in particular descriptions of work performed by Jet Propulsion Laboratory on hydrodynamic stability and by Langley Research Center on a wind tunnel technique for studying the flow of fluid over a surface by use of multilayered, multicolored coatings. That, says DiaSys' president Todd DeMatteo, provided the key to solving the OSA problem.

"The *NASA Tech Briefs* articles led us to aerospace studies on fluid dynamics, especially those with regard to the characteristics of airflow and how it parallels fluid motion. We found that biological fluids actually behave like air in a controlled system like the R/S 2000. Taking advantage of the information presented, we were able to design the OSA to be aerodynamically — and therefore fluid-dynamically — correct."

DiaSys patented the R/S 2000 and introduced it to the market. DiaSys is now developing several additional products based on the same technology, products designed to automate and standardize laboratory procedures used in microscopic examination and manipulation of other body fluids, such as feces, sperm and blood.



# Breast Biopsy System

Health and Medicine

Shown **below** are two Charge Coupled Devices (CCDs), high technology silicon chips that convert light directly into electronic or digital images, which can be manipulated and enhanced by computers.

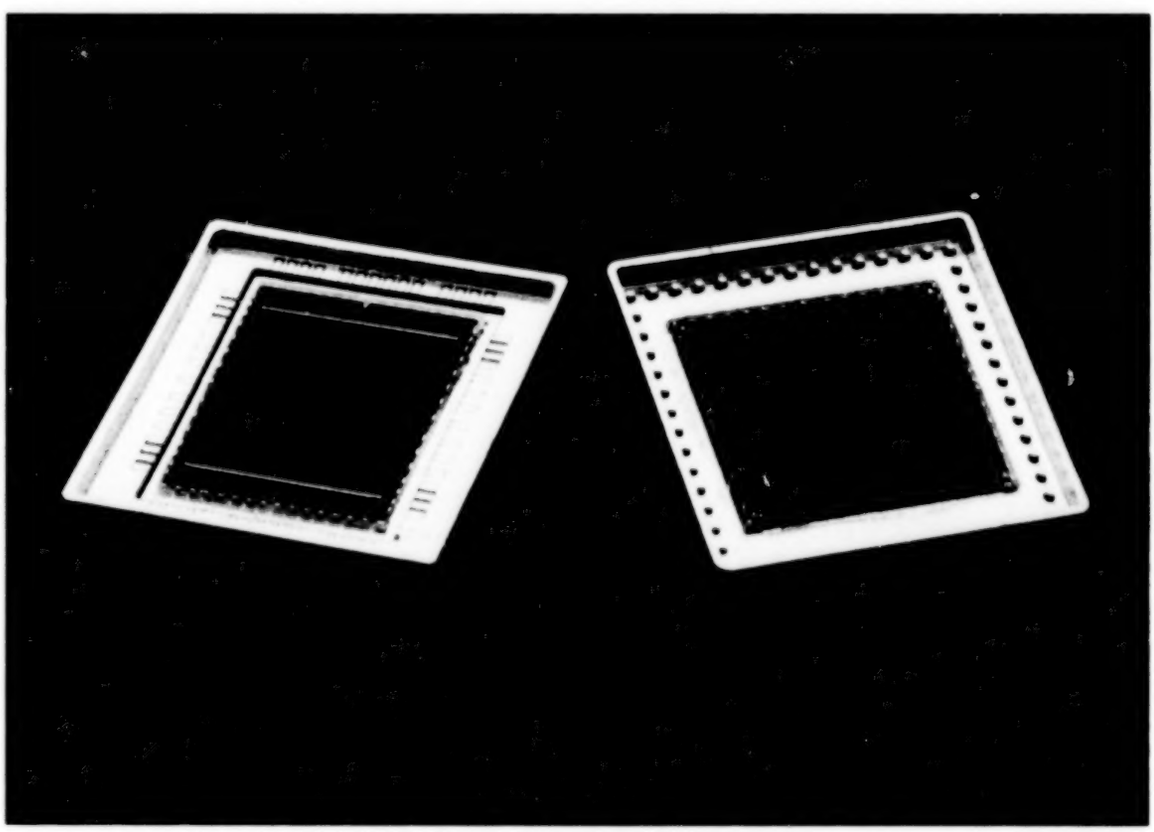
The CCD on the left is an advanced, extrasensitive device developed for NASA's Hubble Space Telescope by Scientific Imaging Technologies, Inc. (SITe), Beaverton, Oregon. The virtually identical CCD on the right is a commercial derivative of the Hubble device that has contributed importantly to a new, non-surgical and much less traumatic breast biopsy technique.

The new technique, which is replacing surgical biopsy as the method of choice in many cases, is saving women time, pain, scarring, radiation exposure and money. Known as stereotactic large-core needle biopsy, it is performed — under local anesthesia — with a needle instead of a scalpel and it leaves a small puncture wound rather than a large scar. Radiologists predict that the needle biopsy technique will reduce national health care costs by $1 billion a year but the potential is even broader, because the imaging system can be used for routine (non-biopsy) breast examinations.

The system that makes possible the new technique is the LORAD Stereo Guide™ Breast Biopsy System, which incorporates SITe's CCD as part of a digital camera system that "sees" a breast structure with x-ray vision. The Breast Biopsy System is produced by LORAD Corporation, Danbury, Connecticut. By mid-1994, LORAD had produced some 350 units, which were in service mostly for biopsy procedures. By mid-1995, it is expected that full digital breast units will be available for routine mammographic examinations.

The technology breakthrough that spawned the LORAD system originated at Goddard Space Flight Center, where scientists are developing the Space Telescope Imaging Spectrograph, due to be installed on the Hubble observatory in 1997. The Goddard development team realized that existing CCD technology could not meet the demanding scientific requirements for the instrument.

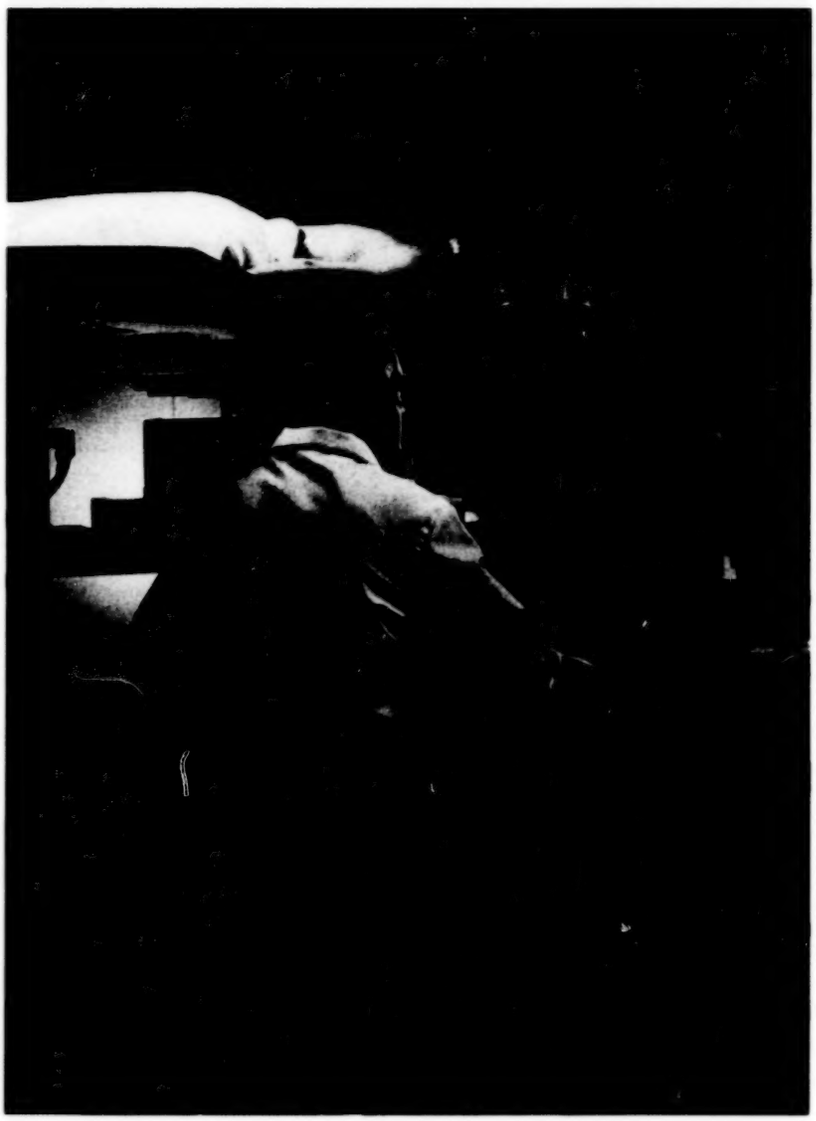
Goddard therefore contracted with SITe to develop an advanced, thinned, supersensitive CCD that could be manufactured at lower cost. SITe was able to meet the NASA requirements, and the company applied many of the NASA-driven enhancements to manufacture CCDs for the



digital spot mammography market. This was a natural technology transfer due to the common requirements for astronomy and mammography: high resolution to see fine details; wide dynamic range to capture in a single image structures spanning many levels of brightness; and low light sensitivity to shorten exposures and reduce x-ray dosage. The resulting device images breast tissue more clearly and more efficiently than conventional x-ray film screen technology, and the Hubble-derived CCD is now leading the field of digital breast imaging, according to medical specialists.

In the LORAD breast imaging system, a special phosphor enables the CCD to convert x-rays to visible light, which provides the digital camera with x-ray vision. The patient lies face down with one breast protruding through an opening in a specially-designed table; the imaging device is mounted under the table. The radiologist locates the suspected abnormality with the stereotactic imaging device by taking images of the suspect mass from two different angles. On the basis of those two images, the computer determines the coordinates of the abnormality and the radiologist extracts a tiny sample from that spot with the needle. The patient can walk out of the office minutes after the procedure and resume normal activities. At **right**, a physician is studying the images acquired by the LORAD Stereo Guide Breast Biopsy System.

Although stereotactic location is also accomplished by use of x-ray film, radiologists say that the new digital imaging device cuts procedure time by one-half to one-third and exposes patients to only half the radiation of the conventional x-ray film method. Additionally, digital images can be computer-enhanced to sharpen details. Studies show that the new procedure, which can be done in a physician's office at a cost of about $850, is just as effective as traditional surgery, which costs about $3,500.



™ Stereo Guide is a trademark of LORAD Corporation

# Broadening the Earthscan Industry

Among environment-related technology transfers is a NASA/private sector partnership effort to expand commercial remote sensing

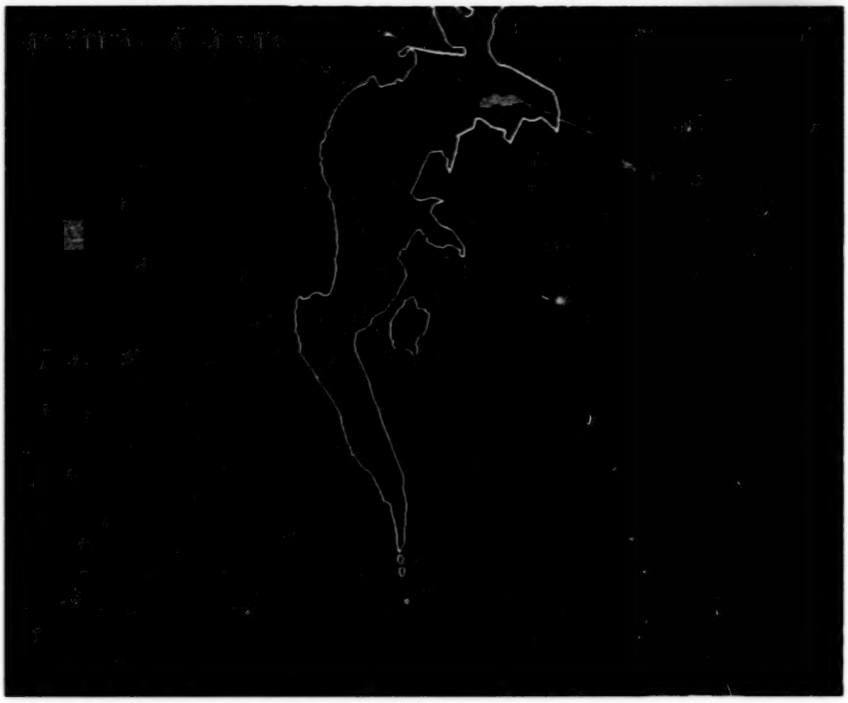
Remote sensing is the process of acquiring physical information from a distance, for example, obtaining data on Earth features from sensors aboard satellites or aircraft. These sensors detect various types of radiations emitted by or reflected from objects on Earth and, because each object has its own special "signature," the data can be interpreted to tell the difference between one kind of vegetation and another for example, or between clear and polluted water, or between densely populated urban areas and lightly populated farmland.

This type of information is being put to practical use in agricultural crop forecasting, land-use management, water quality evaluation, mineral and petroleum exploration, rangeland and forest management, and scores of other applications. Users of remotely sensed data are supported by a small but growing industry that provides computer processing, data analysis and interpretation services.

NASA seeks to accelerate the growth of this "Earthscan" industry because expansion of commercial remote sensing offers broad economic potential for the nation. Among a number of mechanisms designed to promote remote sensing is the Visiting Investigator Program (VIP) managed by Stennis Space Center.

VIP is directed toward small companies who might be able to use remote sensing profitably in their businesses but who do not have much money to invest in exploring new technologies. VIP costs them nothing but their own employees' travel expenses. A prospective VIP participant submits a proposal involving use of remote sensing in an actual project. If the proposal is accepted, Stennis Space Center acquires the remote sensing data, provides instruction in the use of remote sensing software and hardware, and guidance in executing the project. It's a low risk opportunity for companies to develop new capabilities they can market.

An example of a VIP project is the work of Law Environmental, Inc., Kennesaw, Georgia, a professional engineering and Earth sciences consulting firm. Law proposed a VIP project in which remote sensing would be applied to one phase of a broad environmental assessment the company was undertaking for a client. The client operates an electricity generating plant near Panama City, Florida that draws in cooling saltwater from one point in adjacent St. Andrews Bay and releases a heated water discharge into another part of the bay. Law's study was intended to evaluate the effects of the heated discharge on local aquatic life. Stennis Space Center provided the remote sensing data that enabled Law to produce images of the thermal "plume," the water area affected by the heated discharge. The plume's shape, the area it covered and the distribution of surface temperatures were determined under the "worst case" conditions of summer, low water level (low tide) and high water level (high tide). After the plume information was gathered, Law studied selected plant and animal life in



*This image shows the actual temperatures of heated water being discharged into a Florida bay from a generating plant. It was part of a broader study of the power plant's impact on plant and animal life in the bay, conducted in a NASA program to help private firms capitalize on the potential of commercial remote sensing.*

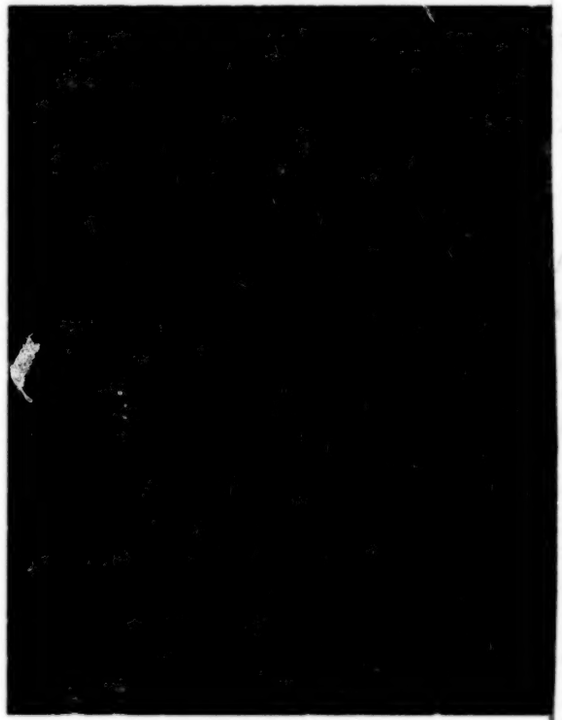
the discharge area for comparison with similar life in an unaffected control area. Law was able to conclude that the plant and animal life were not substantially affected by the generating plant's heated discharge.

VIP gave Law Environmental hands-on experience in a technology new to company employees and increased Law's competitiveness by adding remote sensing to the company's conventional ecological assessment techniques. Law has since conducted a number of commercial remote sensing projects.

A similar beneficial result was reported by Subra Company, Inc., New Iberia, Louisiana, a company that offers commercial environmental studies and analytical services. Under the VIP program, Subra teamed with Stennis to develop software models for tracking the impact of nonpoint source (NPS) pollution. Point source pollution is typically discharge from industrial facilities through pipes or conduits; NPS pollution is transported by water movement over land, the "runoff" that picks up pollutants and carries them into rivers, lakes, wetlands and ground water. Cities with populations above 100,000 are now required to identify NPS and take steps to control it, but tracking NPS by conventional means is a labor intensive job involving a lot of field study.

With Stennis' help, Subra analyzed a test area in Calcasieu River Basin, Louisiana, using satellite data to produce a land cover classification of the whole area as a first step. Subra added data on soil permeability, elevation, slope, hydrography, drainage basins and NPS locations to make a complete remote sensing/geographic information system that can be used by government agencies for planning pollution control actions. In VIP, Subra learned how to use remotely sensed data to compress the time required for a difficult task and thus expanded its range of expertise; the company is now offering technical services based on remote sensing to industrial clients.

By April 1994, 24 companies had participated in Stennis Space Center's VIP; as a result of their VIP experiences, 13 companies had developed new products or services.



*A composite image rates the impact of nonpoint pollution sources, such as rain runoff, on an area of Calcasieu River Basin, Louisiana (shades of green/blue are low impact areas, yellow/red high impact areas). The study project gave a Louisiana company valuable hands-on experience in applying remotely sensed data.*

# Earth Observation

Environment and Resources Management


NASA's effort to help private industry develop and commercialize new applications of remote sensing includes, in addition to the VIP program (see page 48), a government/industry cooperative program known as EOCAP, for Earth Observation Commercial Applications Program.

EOCAP provides government co-funding to encourage private investment in, and broader use of, NASA developed technology for gathering and analyzing information about Earth's land and ocean resources. Like VIP, EOCAP is managed by Stennis Space Center, but the programs differ in other ways: VIP generally involves short-term projects of three to six months and NASA funds the project; EOCAP projects can run three years or more and funding is shared on a 50-50 basis.

An EOCAP example is an important project that offers benefit potential to U.S. pipeline companies. These companies face ever-increasing operating and regulatory pressures that require mapping, inventories of facilities, pipe inspections, rehabilitation, environmental reporting, and facilities safety and notification programs. Keeping track of the facilities and updating associated records is a monumental task.

One obvious answer is automation and several pipeline companies have implemented Automated Mapping/Facilities Management/Geographic Information Systems (AM/FM/GIS).

But setting up an AM/FM/GIS and keeping it up to date is a costly and time-consuming endeavor. The cost of new photogrammetric mapping is significant; county and U.S. Geological Survey maps are not sufficiently detailed; and manual handling of hundreds of thousands of aerial photos is difficult.

James W. Sewall Company, Old Town, Maine, an AM/FM/GIS consulting firm, saw a solution. Looking for ways to help its customer -- Algonquin Gas Transmission Company, Boston, Massachusetts -- Sewall proposed an EOCAP project to develop a computerized system for storing and retrieving digital aerial photography of pipeline rights-of-way. The system would provide an accurate inventory of rights-of-way locations and pipeline surroundings for engineering, maintenance and regulatory purposes. Other project objectives included adapting a

NASA-developed digital camera system for pipeline monitoring, and uniting the digital aerial images acquired with an AM/FM/GIS system being developed by Algonquin to replace its manual method of mapping and information management.

NASA accepted the proposal and Stennis Space Center joined with Sewall, Algonquin and NASA's Science and Technology Laboratory (located at Stennis) to implement the development effort. Begun in 1990, the project was largely concluded in 1993; the final phase, full operation of Algonquin's image-based AM/FM/GIS known as MAPS (Mapping Algonquin's Pipeline System), was nearing completion in 1994.

An important byproduct of the EOCAP project was Stennis Space Center's development of the Digital Aerial Rights-of-way Monitoring System (DARMS), a PC-based charge coupled device digital camera integrated with a large capacity recorder. DARMS was installed in one of Sewall's twin-engine Aztec aircraft for operational testing and development of imagery for the EOCAP project. In addition to its use in pipeline management, DARMS has excellent potential in such applications as transportation, municipal map updating and environmental monitoring; its advantage over traditional aerial photography is substantial time and money savings, particularly when the digital imagery is used in an AM/FM/GIS.

**At left,** Sewall employee Richard St. Pierre is working on a DARMS plot. **At right above** is a closeup of a DARMS screen showing the land image in black and white and the pipeline in false color, highlighting the important map features for the client. **At right** is a sampling of DARMS maps and the 8-millimeter Exabyte tapes used to collect and store the data from a pipeline survey.

The EOCAP experience enabled Sewall to develop new products and to expand its customer base in pipeline monitoring and other markets. Since undertaking the project, Sewall has tripled the size of its AM/FM/GIS division and extended its operations into the international marketplace. And for Sewall's customer, Algonquin Gas Transmission, the EOCAP project has provided technology for managing regulatory requirements more efficiently and more accurately.

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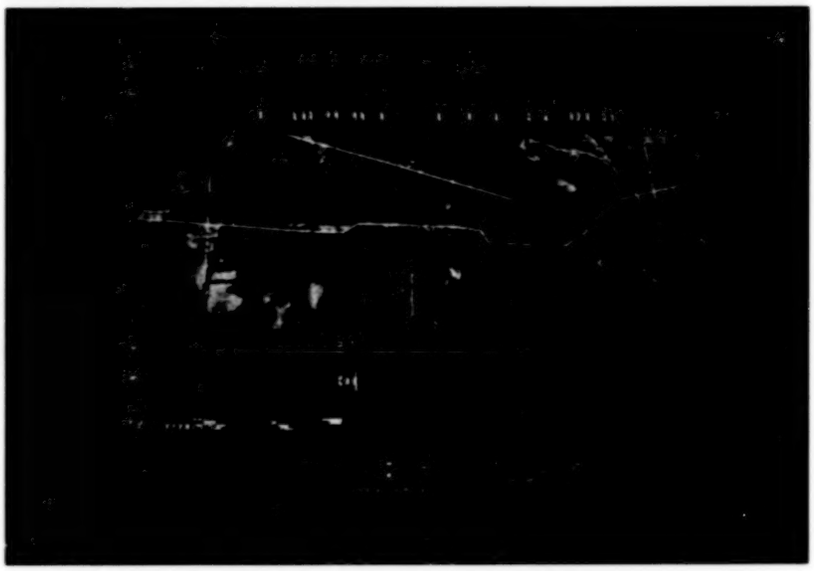
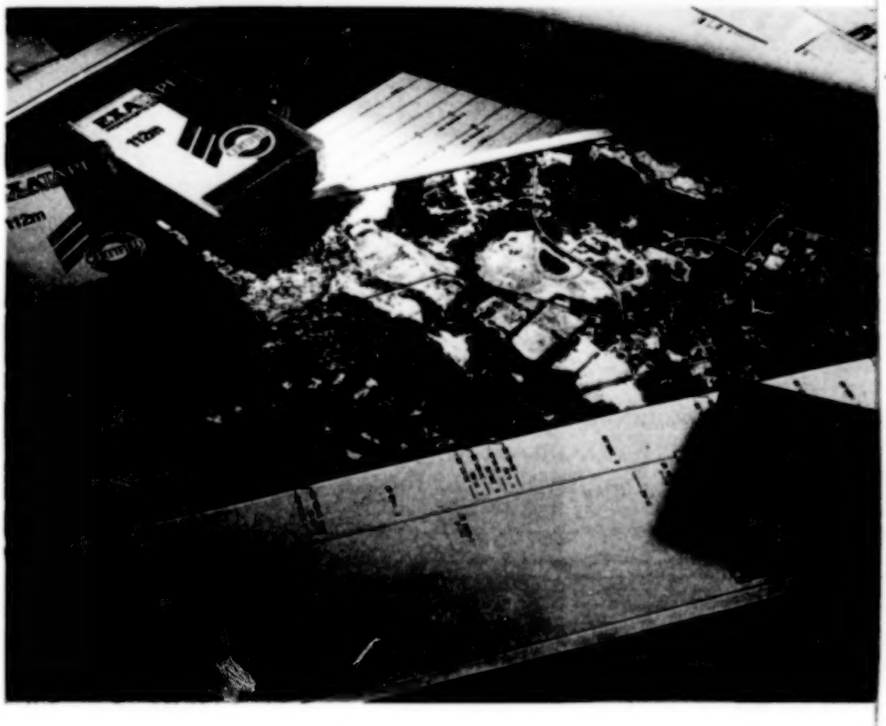




# Earth Observation (Continued)

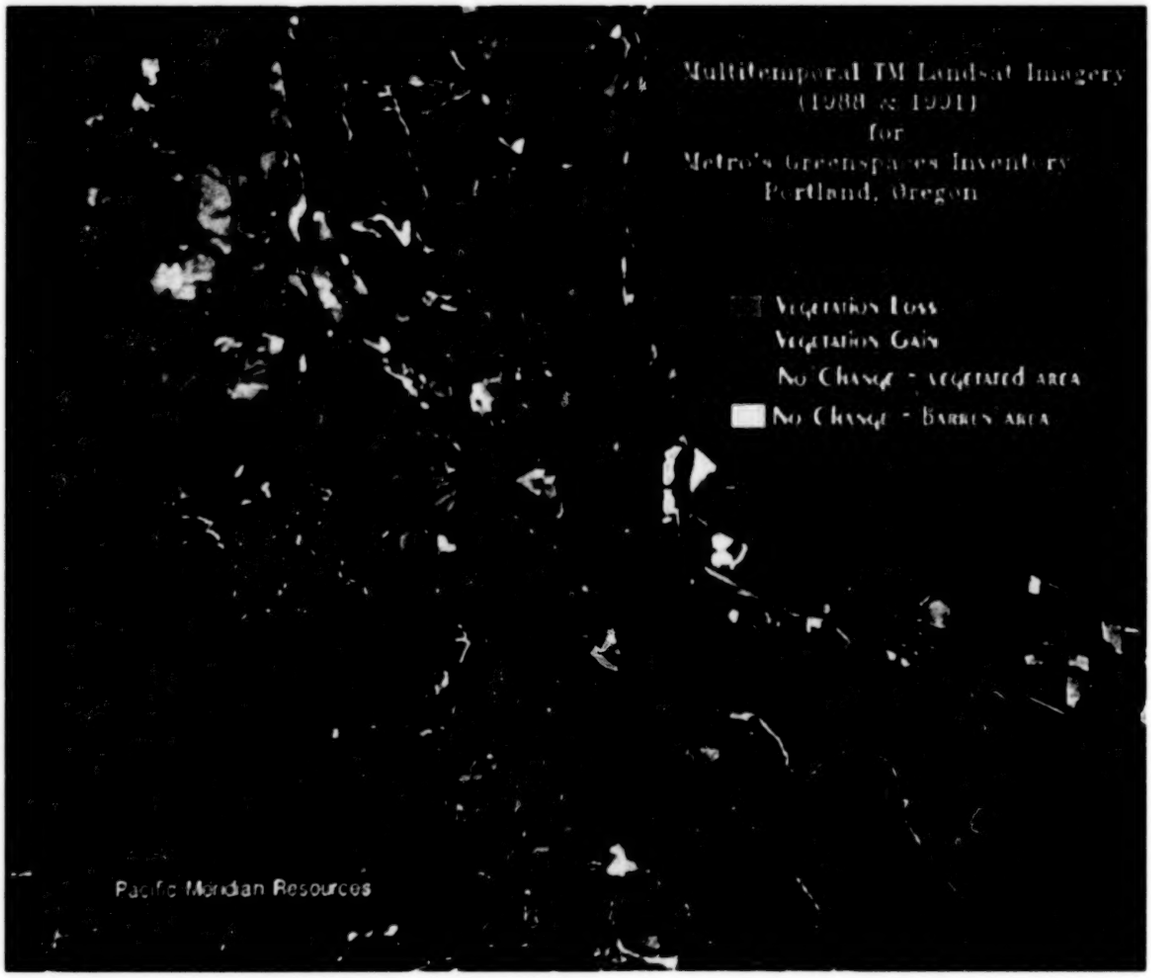


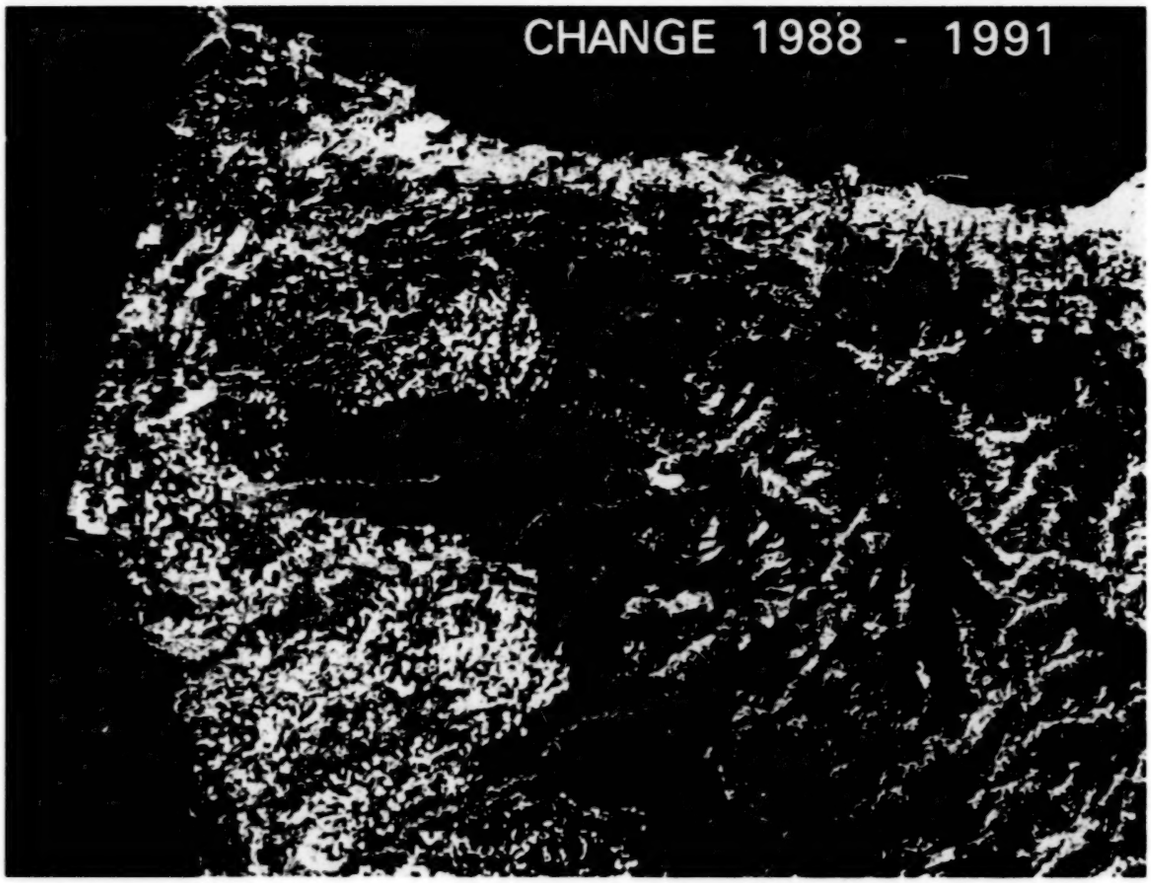
Changes on Earth's surface are becoming more extensive and they are occurring more rapidly than ever before. The changes become more significant as the planet's population grows and the available land base declines. Planners and resources managers need a reliable way to assess the consequences of change by detecting, quickly and accurately, changes in the way land is used.

Pacific Meridian Resources, Emeryville, California teamed with NASA on an EOCAP project to develop a system for monitoring changes in land cover and land use, incorporating the latest change detection technologies (which have advanced significantly in recent years) and factoring in the economic, political and biological issues relevant to a particular land use problem.

The goal of the project was not to develop new technologies, but to tailor existing technologies to a comprehensive system that could be commercialized for a variety of users. The objective, as stated by the project team, was "to take existing geographic information system (GIS) and satellite image processing technologies and develop production-oriented methods and services for assessing and monitoring land use/land cover change."

The EOCAP project was a broad-based effort involving NASA, the Portland (Oregon) Metropolitan Service District, the Washington State Department of Natural Resources, other government agencies and private organizations; each contributed funds, imagery and/or personnel time. The primary thrust of the project was development of a Land Use and Cover Change Analysis System of meth-






ods to assess land cover change over time; land cover changes would then be related to land use change, which in turn would be associated with demographic and economic change.

For change detection input, Pacific Meridian used imagery acquired by the Thematic Mapper (TM) aboard the NASA-developed Landsat satellite, specifically summertime scenes of the Portland metropolitan area taken three years apart (1988-91). The major aim was to identify areas that had sustained substantial loss of vegetation, principally through timber harvesting and developmental activities. **At left** is a Landsat TM change detection image covering the Olympic Peninsula that shows (in magenta) areas that sustained an appreciable loss of vegetation, green a gain, blue no change in a vegetated area, white no change in a barren area (no change means a gain or loss of less than 30 percent of the vegetation cover). **Above** is a summary image of 1988-91 change in the Portland Metropolitan District; red indicates a loss of vegetation, green a gain, blue no change in a vegetated area, white no change in a barren area (no change means a gain or loss of less than 30 percent of the vegetation cover).

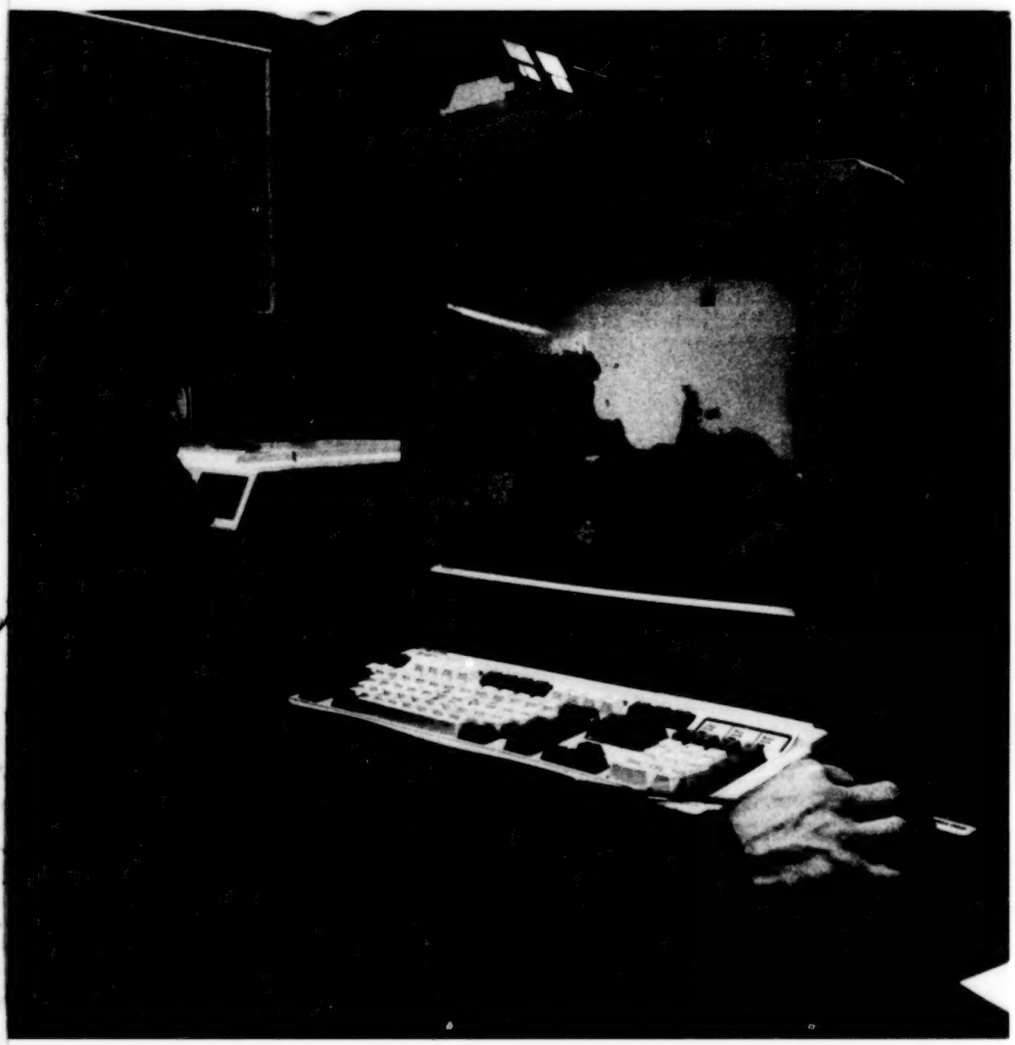
Pacific Meridian was successful in accomplishing the primary EOCAP objective, development of image processing methods to identify change, measure the extent of change, and update GIS maps to incorporate the change. The company plans further investigation to link land cover/land use change to environmental and economic impacts; additionally, it plans to increase marketing activities to boost the exposure and acceptance of its change detection products.

Pacific Meridian considers the EOCAP project "a vital component for the development of future services to its clientele." EOCAP participation helped Pacific Meridian to stay on the cutting edge of change detection techniques by providing R&D funding, a commodity not often available to young, rapidly growing companies. Partially as a result of the EOCAP project, Pacific Meridian has grown from six employees in a single office to 60 in five offices, and annual revenues have increased from $200,000 to $3,500,000.

# Dead Sea Scrolls

Environment and Resources Management

**Below**, Dr. Gregory Bearman, a physicist and remote sensing specialist at Jet Propulsion Laboratory (JPL), is viewing a fragment of the Dead Sea Scrolls that had mysteriously deteriorated to the point where the text was undecipherable. The previously invisible lettering on the screen was made distinguishable by use of advanced multispectral imaging techniques originally developed at JPL for Earth remote sensing and planetary probes. The work, which produced a technique with potentially important implications for archeology, was conducted by a consortium of researchers from four organizations.



Provided by the Getty Conservation Institute, Marina del Rey, California, the scroll fragments appear to the naked eye to be totally ruined and the black ink typically cannot be distinguished from the scroll's age blackened parchment.

Bearman and his colleagues then subjected the fragment to examination by highly sensitive electronic cameras and digital image processing techniques. One scanning camera uses a sensor known as a CCD (charged coupled device) that acquires images in digital form and serves as the camera's electronic film. Use of the CCD enabled a look at the fragment in longer wavelengths beyond the sensitivity of infrared film. Imaging in these wavelengths increased the contrast between ink and parchment and, with computer image enhancement techniques, made legible a string of Hebrew letters that translate into "He wrote the words of Noah."

The project drew on technology earlier developed by JPL and a contractor in a mid-1980s project for the National Archives. They used CCDs originally developed for the Hubble Space Telescope and the Galileo planetary probe as the basis of a system, now in use at the Archives, that regularly scans historical documents to see if there have been any deteriorating changes. The computerized system provides better and earlier detection of change than previous methods of monitoring documents.

The team of researchers in the scroll enhancement project included, in addition to Bearman, Dr. Bruce Zuckerman, a Semitic languages scholar at the University of Southern California's School of Religion; Ken Zuckerman, a photography specialist at West Semitic Research; and Joseph Chiu, a student at California Institute of Technology, JPL's parent organization.

# War Damage Assessment

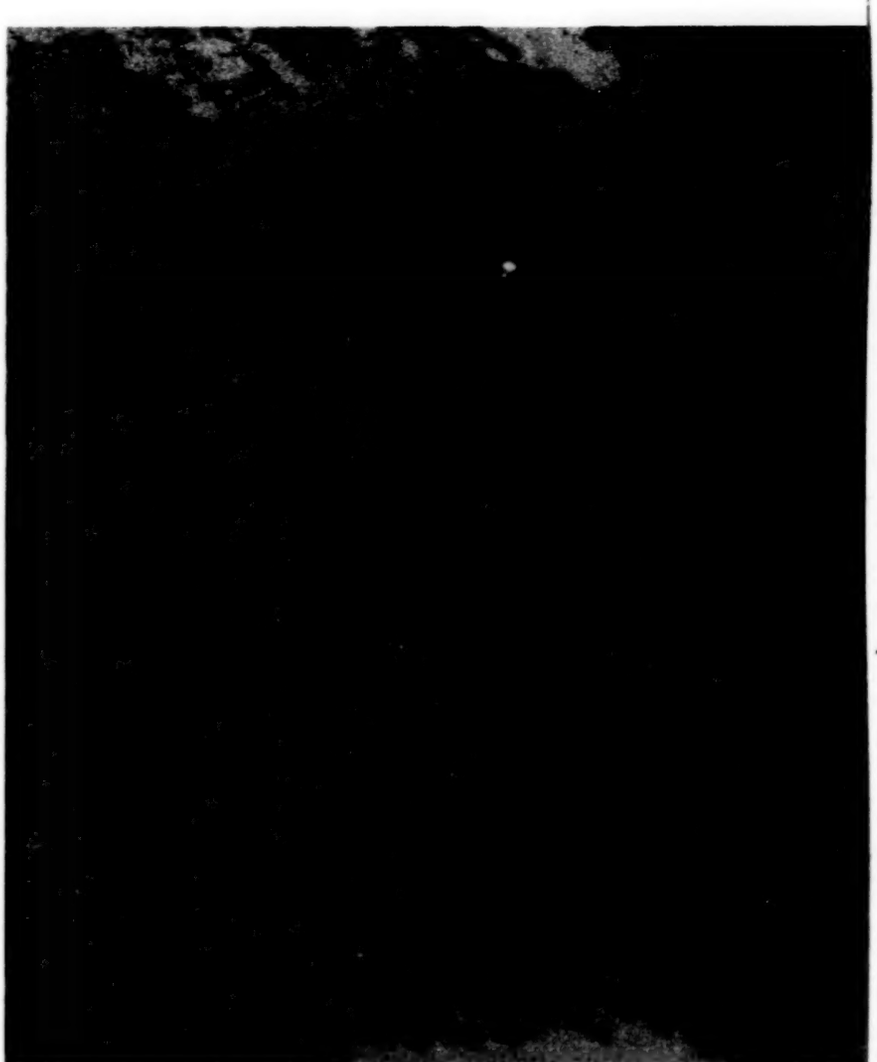
The Persian Gulf war of 1991-92 caused significant change to the desert environment of the State of Kuwait, particularly creation of hundreds of "oil lakes" by oil released from damaged wells. These lakes constitute a hazard to the Kuwaiti atmosphere, the underlying soil and ground water reservoirs. The lakes must be carefully monitored because their locations, shapes, sizes and depths are subject to rapid change from evaporation, migration of the oil, infiltration of the oil into the ground, or covering of the lakes by moving sand dunes.

An essential first step was accurate mapping of the lakes, accomplished as part of a comprehensive damage assessment of Kuwait based principally on satellite remote sensing. The two-year task was carried out as a joint project of the Boston (Massachusetts) University Center for Remote Sensing, headed by center director Dr. Farouk El-Baz, and the Kuwait Institute for Scientific Research, with funding from the Kuwait Foundation for the Advancement of Sciences.

The assessment team used prewar and postwar imagery for comparison and detection of change; the images were obtained by the Thematic Mapper aboard the NASA-developed Landsat satellite and by the French SPOT satellite. Field measurements were conducted to verify the satellite data and geographic information system methodologies were employed to correlate the data.

**At right** is a typical postwar image of a coastal area south of Kuwait City where a number of the country's major oil fields are located. The black patch in center image represents a vast layer of oil and soot deposited by the plumes of oil well fires; the mixture of oil, soot and sand has hardened into a layer of "tarcrete" up to four inches thick.

Among other damaging effects, the team reported the formation of more than 300 inland oil lakes; significant pollution of a strip of the coastal zone from oil spills; and disruption of the desert "pavement" -- a thin layer of pebbles -- and the vegetation cover. This disruption caused mobilization of fine-grained particles that became the source of dust and sand storms; many new sand dunes have formed as a result of war-related activity and they have begun to encroach on roads and farms.



The total surface area damaged by war activities is more than 5,400 square kilometers, roughly 30 percent of Kuwait's total surface area. This included some 3,500 square kilometers affected by land mines and postwar clearance of mines and unexploded ordnance; almost 1,000 square kilometers covered by tarcrete; areas totaling 500 square kilometers where desert shrubs were destroyed; and some 50 square kilometers covered by oil lakes.

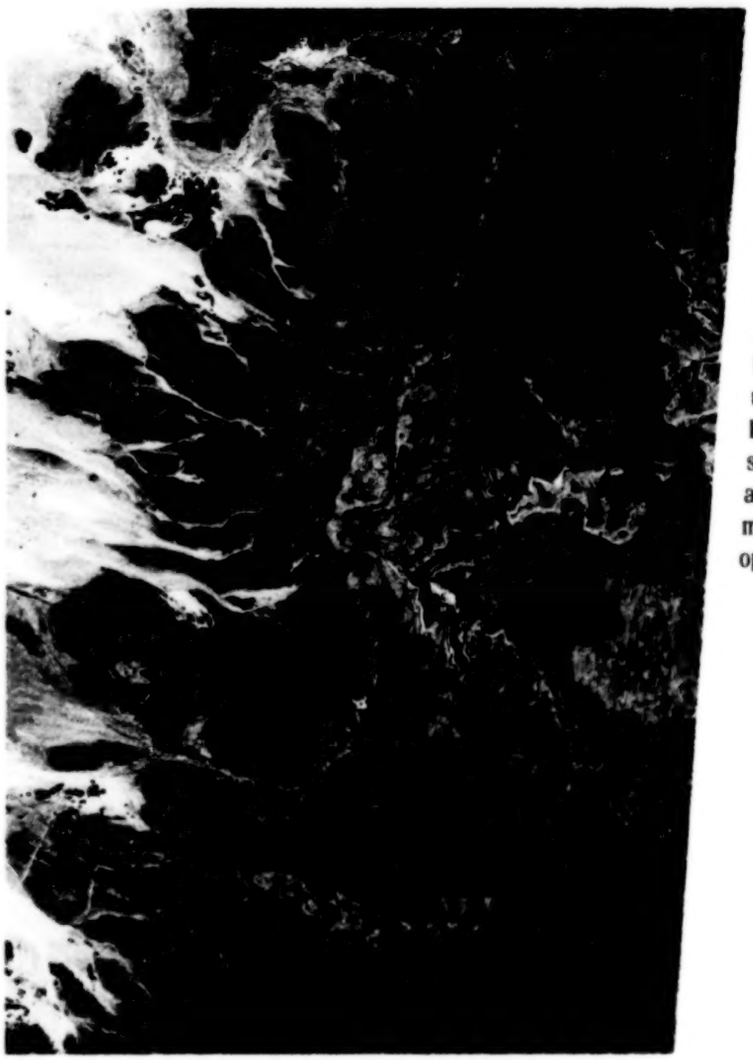
# Oil Exploration Mapping

Environment and Resources Management

In January 1991, Chevron International (Yemen) Limited concluded an agreement with the newly established Republic of Yemen for oil exploration and production sharing in an area of Yemen known as the Shabwah Garden Block, an area characterized by rugged and varied terrain, including low relief desert, high plateaus, towering cliffs and deeply incised drainage.

To support field operations and logistics planning, the company needed detailed geologic and topographic maps, but only small-scale base maps of the area were available. Chevron therefore initiated a remote sensing project to develop a digital elevation model, and to generate large scale images, improved base maps and topographic maps. The job fell to Chevron Overseas Petroleum Inc. (COPI), San Ramon, California and COPI remote sensing supervisor James M. Ellis, with assistance from Chevron Oil Field Research's remote sensing laboratory at La Habra, California.

The remote sensing team used imagery from the NASA-developed Landsat Thematic Mapper (TM) and the French SPOT satellite, combining images from both into composite views to use the best capabilities of each system. **Below** is a TM/SPOT composite image of the Shabwah area typical of those used to extract a great deal of information for support of field operations; the white, gray and light blue shades in the west (left in image) are areas of flat, sandy desert, dry river courses and cobble/gravel surfaces, readily accessible to vehicles; red and pink signify limestone and shale areas; brown represents sandstone and green massive sandstone. The green area at bottom center is an area of steep to vertical canyons and cliffs that bar vehicular operations.



The project was successfully concluded within the specified time of 11 months with delivery to the field of images, greatly improved base maps and unique topographic maps. COPI's James Ellis reported: "This project demonstrates that timely and practical application of remote sensing can support more efficient and cost-effective field operations."

# Mapping Van

**At top right** is a sophisticated mapping van equipped with satellite signal receivers, video cameras and computer systems for collecting and storing mapping data. **At lower right** is a view of the van's interior with Fred Bennett, president of Global Visions, Inc. (GVI), Herndon, Virginia at the control console.

Formally known as the GPSVan System, the vehicle was originally developed by the Ohio State University Center for Mapping, one of NASA's Centers for the Commercial Development of Space (CCDS). It is operated by GVI under license from the Center for Mapping, and the company last year accomplished the first commercial use of the CCDS-developed system, creating a digital map of the 1,000-mile road network in Ohio's Jackson County. Bennett and co-founder Day Shelmire established GVI to commercialize the CCDS technology.

The "GPS" stands for Global Positioning System, a constellation of satellites operated by the Department of Defense to provide highly precise positioning information for aircraft, surface vessels and ground vehicles. The van also has an inertial navigation system, a gyroscopic system that records all forward movement and directional change for brief periods when trees or terrain block out satellite signals. Mapping is accomplished by driving along a road while the GPS receivers record the van's position with an accuracy of one to three meters.

The van also employs two video cameras to scan the local terrain and acquire images whose location is coordinated with the van's position at the time of imaging. Features such as street signs, utility poles, manholes, and roadside structures can be precisely positioned on the base maps. All this data can be fed into a computerized geographic information system (GIS).

Using this system, GVI took just two weeks to map all of Jackson County. The resulting maps, fed into the county's soon-to-be-implemented GIS, will be used initially for tax assessment purposes. However, the GPSVan has much broader potential, according to GVI's Bennett and Shelmire. They are targeting emergency dispatch agencies and fleet delivery companies, who can use mapping data to improve routing and lower transportation costs; providing mapping data for inventories of roadside features to utilities, other businesses and state/local governments for better management of their resources; and providing visual imagery for roadway maintenance planning or for property evaluation by insurance underwriters.

# Waste Site Mapping

Environment and Resources Management

At Davis Monthan Air Force Base, Tucson, Arizona, the Department of Defense maintains a storage facility for thousands of old aircraft that might be restored to service condition in an emergency. Since the 1950s, aircraft considered not restorable have been melted down in on-site furnaces to reclaim the aluminum in their airframes. The process produces aluminum ingots and leaves a gray, ash-like residue known as "dross" which, for decades, was simply dumped in the desert. A dross site and the furnace that produced it is shown **below**.

Dross contains heavy metals such as lead, silver, cadmium and copper. These metals are contaminants and the Pima County Department of Environmental Quality wanted a cost-effective method of locating dross dumps.

Although it had not previously been done, Dr. Larry Lepley of Lepley & Associates, consulting geophysicists in Tucson, and Sandra L. Perry of Perry Remote Sensing, Ltd., Denver, Colorado, felt that the NASA-developed Landsat Thematic Mapper (TM) could be used to screen the area for dross.

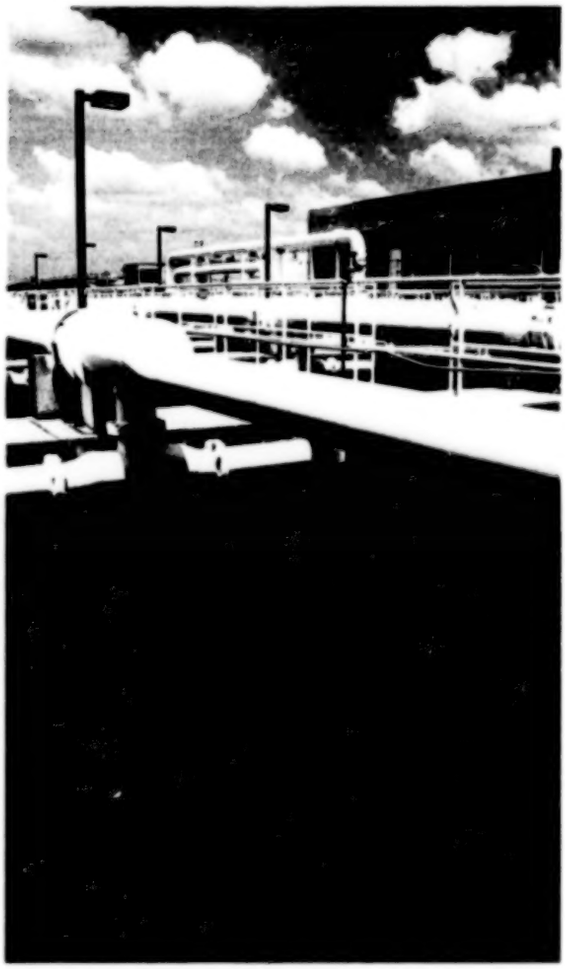
The two contracted to study the TM potential in this type of application. The challenge was the fact that the known dross dumps were typically no larger than 50 meters across, so small in satellite imaging terms that dilution of the dross spectral signature from desert background was inevitable.

Perry succeeded in developing a special two-step procedure in which dross and background were separated by classification of the principal components. Paper color copies of the classified dross target images were scale-matched to a published Tucson area map, and Lepley field-checked the targets. His field evaluation found the mapping accurate where dross dumps were 50 by 50 meters or larger. The Perry/Lepley report concluded that "given sufficient spectral contrast with the background, contaminated soil areas of only a few pixels in area can be mapped with TM data," opening the door for similar applications. **Above** is a TM image of the Tucson area showing a dross dump as a tiny red dot (circled).

# Process Analyzer

Biotronics Technologies, Inc., Waukesha, Wisconsin has introduced to the market the first of a planned family of ChemScan* products for use in environmental applications. Intended for initial marketing to the water and wastewater treatment industries, the product is the Model UV-6100 Process Analyzer, which operates simply and cleanly by analyzing the light absorbance characteristics of a sample. The UV-6100 eliminates tedious manual sampling, replaces independent "grab sampling" with on-line data collection, and gives an operator the information needed to control a process more efficiently, says Biotronics.

**Below** is a pipeline of the City of Tampa (Florida) wastewater treatment facility, which is testing the analyzer for Biotronics. A ChemScan analyzer **(right)** monitors the water flowing through the pipes on a real time basis. The ChemScan UV-6100 is a spectrometry system originally developed for NASA under a Small Business Innovation Research contract, then refined for the commercial market. Operating in the ultraviolet (UV) wavelength range, the UV-6100 simultaneously detects hundreds of individual wavelengths absorbed by chemical substances in a process solution, then it quantifies the information.



The spectral data is processed by the analyzer and compared with calibration files stored in the system's memory, in order to calculate the concentrations of chemical substances that cause absorbance of UV light in specific patterns. The comparison permits an accurate qualitative and quantitative analysis of the substances being monitored.

Applications include detection of biological nutrients (including nitrates, nitrites and phosphates); dissolved iron levels in raw water supplies; ion exchange breakthrough; chlorination/dechlorination residuals; softwater discharge profiles; heavy metals; and toxic substances. The information provided by the analyzer can be used to optimize feed rates, set retention times, determine aeration rates, assure regulatory compliance, prepare reports and control processes.


* ChemScan is a registered trademark of Biotronics Technologies, Inc.

# Contamination Analyzer

Environment and Resources Management

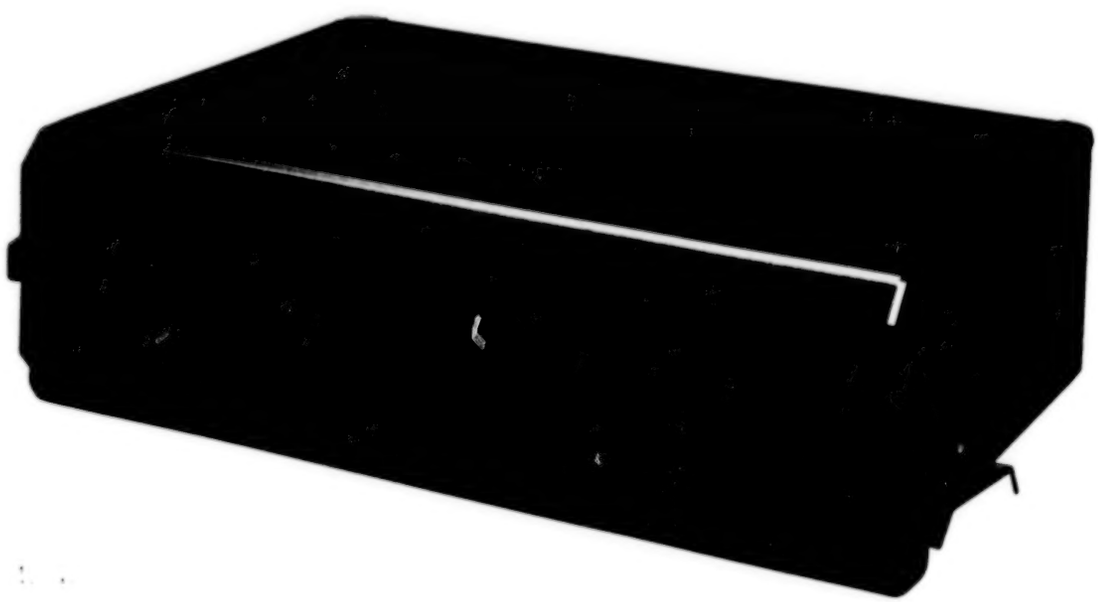
**Below** is the Sievers Model 800 Total Organic Carbon (TOC) Analyzer, manufactured by Sievers Instruments, Inc. and based on technology originally developed for use on the International Space Station. The company describes the analyzer as the "ideal solution for on-line organics measurement in any stage of water purification, from feedwater to ultrapure process water."

Measurement of the total organic carbon content of water is a widely used method of assessing the level of contamination caused by organic compounds. TOC measurement is important in high purity waters used in power generation, pharmaceutical production and electronics manufacture; the presence of even trace levels of organic compounds can cause defects in manufactured products or corrosion in power generation equipment. TOC analysis is similarly important in determining contaminant levels in industrial and municipal wastewater.

In the analytical methods used on Earth for more than 30 years, organic compounds in a water sample are completely oxidized to form carbon dioxide, the amount of which is measured. The standard technique for TOC measurement involves bubbling a compressed gas into the water to purge the carbon dioxide formed by the oxidation step, and a large infrared detection system for measuring the amount of carbon dioxide purged, which requires daily calibration. This method was not suitable for space station use. To monitor closed-loop water recycling systems in orbit, NASA sought a small, compact TOC analyzer with gravity-independent components, one that would employ minimal use of chemical reagents and would not require frequent calibration or maintenance.

Sievers Instruments worked with McDonnell Douglas Space Systems Company on a NASA-funded project that led to development of a new technique for TOC measurement, in which a strong chemical oxidizing agent and ultraviolet light are used to convert the organic compounds to carbon dioxide. The carbon dioxide passes from the water sample through a membrane and into a stream of deionized water, where it becomes ionized; the amount of ions is determined by measuring the conductivity of the deionized water. The new technique is highly sensitive, requires calibration only once a year, does not require compressed gas to purge the carbon dioxide from the sample, and is capable of operating in microgravity.

This technology has been commercialized in the Sievers Model 800 TOC Analyzer. Introduced to the market in 1993, the instrument is being used to monitor organic contaminants in electric power generation, pharmaceutical production, biotechnology, semiconductor manufacturing and other industrial/environmental applications. The low maintenance feature required for the space system has been included in the commercial instrument; the only maintenance required is quarterly replacement of the chemical reagents.



# Oil Spill Cleanup

A new way of cleaning up oil spills by "bioremediation" is being marketed by Petrol Rem, Inc., Pittsburgh, Pennsylvania. Invented by Petrol Rem chief scientist Joseph A. Resnick, the product is known as PRP™, for Petroleum Remediation Product. It incorporates technology related to fabrication of microcapsules developed by Marshall Space Flight Center and Jet Propulsion Laboratory. Resnick, at left **below**, is pictured with a technician in the company's production facility.

PRP consists of thousands of microcapsules, tiny balls of beeswax with hollow centers. The hollow core contains live microorganisms and nutrients to sustain them. Water cannot penetrate the microcapsule's shell, but oil can, by osmosis. The encapsulated microorganisms — known as lipolytica — are capable of degrading hydrocarbons by secreting enzymes that break down oil into base elements of carbon dioxide and water. As oil flows through the microcapsule's shell, it is consumed and digested by the microorganisms. When PRP explodes — due to pressure buildup — the enzymes, carbon dioxide and water are released into the environment. The process leaves a residue that is environmentally safe and can be consumed by fish as food.

For cleaning up an oil spill, PRP is used in conjunction with an apparatus also developed by Petrol Rem. The Bio-Boom™ is an oil spill containment system available in a number of sizes or tailored to a user's requirements. The Bio-Boom, shown being deployed **above**, has a flotation device that keeps the boom on top of the water and prevents contaminated water from spreading into nonpolluted water.

A 10-foot-long Bio-Sok™ cartridge fits into a mesh enclosure on the boom. The cartridge contains an oil-absorbent material and seven pounds of PRP. The oil-absorbent material "wicks" the contaminated water toward the PRP, the oil penetrates the shells of the microcapsules and is digested by the microorganisms.

Work performed at Jet Propulsion Laboratory demonstrated the feasibility of encapsulating live cells and Petrol Rem chief scientist Resnick employed that technology in developing PRP. Technology developed at Marshall Space Flight Center for experiments in orbital production of microspheres provided the basic design of the delivery system that protects encapsulated cells from the water but allows passage of hydrocarbons through the microcapsule's shell.

™ PRP, Bio-Boom and Bio-Sok are trademarks of Petrol Rem, Inc.

# Oceanographic Instrument

Environment and Resources Management

**Below** is a Fast Repetition Rate Fluorometer, an oceanographic instrument being marketed by Environmental Monitoring Systems (EMS) division of MillWest Corporation, Dumas, Texas. The first commercial units were shipped in 1994 to Germany's Alfred Wegener Institute.

Developed under NASA contract, the FRR fluorometer is a computer-controlled instrument for measuring the fluorescence of phytoplankton, the microscopic plant forms that are the major sources of sustenance for animal life in the oceans; such measurements provide scientific information on ocean activity and productivity. The instrument measures the chlorophyll biomass (the total amount of phytoplankton in a water sample) and the parameters of photosynthesis in phytoplankton (photosynthesis is the process by which plant cells produce carbohydrates by absorbing carbon dioxide and water in the presence of chlorophyll and light, and release oxygen as a byproduct). **At right,** Dr. Zbignew Kolber works with data collected by the sensor, which was lowered into the ocean and towed by ship through an area being simultaneously investigated by satellite instruments; test printouts of FRR fluorometer and satellite data are compared.

Among advantages cited for the Fast Repetition Rate Fluorometer,it is non-destructive and does not harm the microplants, and it can be used *in situ*, eliminating the need to remove a sample from its natural surroundings. The instrument is equipped with a powerful microcomputer, a data logger, an internal battery pack and a flexible communications channel.

The fluorometer was originally designed at Brookhaven National Laboratory, Long Island, New York. Development was begun in 1990 by G. Miller Machine Company, Dumas, Texas, parent company of EMS. In 1992, Jet Propulsion Laboratory awarded the company a NASA Small Business Innovation Research contract to complete the development. Although the fluorometer is technically commercialized, EMS is continuing work on the SBIR contract, refining the electrical components and writing software for incorporation in later versions of the instrument.

# Water Conditioner

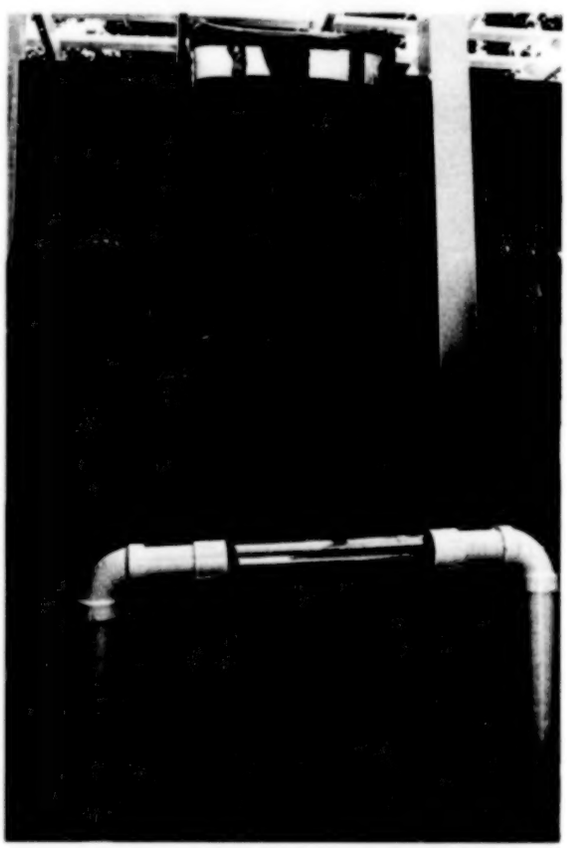
**At right** is an Aqualizer, a cartridge for a water conditioning system being marketed by C-Text, Inc., Chambersburg, Pennsylvania. Developed by inventor Luis Gomez of Miami, Florida, it is based on NASA silver ionization technology used to purify drinking water aboard the Apollo spacecraft (see page 86).

The Aqualizer is designed to cleanse water with minimal use of chemicals by stabilizing the ions in the water. In recreational applications, such as swimming pools and spas, it kills bacteria and algae with reduced use of the chemical substances otherwise employed for that job. In industrial applications, such as cooling towers, steam boilers or heat exchangers, it inhibits the buildup of scale deposits and removes deposits previously accumulated.

The Aqualizer operates on the principal of catalytic water conditioning. It is a non-electrical passive device consisting of a stainless steel pipe length (upper item at **right**) with a helical core (lower item) made of iron, copper, zinc, tin, silver and nickel. The cartridge pictured is two inches in diameter and one foot long, but the manufacturer offers the device in a variety of sizes — from a half-inch to 48 inches in diameter with varying lengths — depending on the quantity of water to be treated.

When water passes through the electro-chemical chamber, the presence of dissimilar metals triggers an ionization effect that stabilizes the water, or alters its molecular structure. The ionization reaction causes salt, rust and scale to be suspended in the water and to clump together so they are easily removed by the pool's filter. This process, says the company, inhibits the growth of bacteria and algae and uses as little as 10 percent of the chemicals normally used.

In addition to industrial water conditioning and pool/spa recreational applications, Aqualizer customers are using the product in dishwashers, drinking fountains, dry cleaning equipment, filter systems, jacuzzis, heat exchangers, ice machines, ornamental fountains, irrigation systems and water heaters. At **right**, the Aqualizer cartridge (foreground) is fitted into the filtration unit of a home pool.



# Home Insulation

Environment and Resources Management

**Below**, a technician is inspecting a home insulation system that incorporates "radiant barrier" technology originally developed for NASA's Apollo lunar landing program. The Radiant Barrier insulation is an adaptation of a highly effective aluminum shield used on the Apollo spacecraft and other space systems as a radiation barrier that held in or kept out heat, cold air and water vapor.

The radiant barrier is part of a broader Guaranteed Watt Savers™ (GWS) system of "total home low energy consumption" being marketed as a joint venture of Guaranteed Watt Savers System, Inc., Charlotte, North Carolina and Smart-House Consultants, Incorporated, Oklahoma City, Oklahoma. The GWS design technique combines space technology, advanced building technology and an engineering systems design approach to effect significant savings in home heating and cooling costs.

Under the GWS systems, plans for a new home are computer-analyzed relative to expected heat loss and gain, then the company provides specifications — designed specifically for each structure — as to heating, cooling, ventilation and insulation. The company inspects the work of the heating, air and insulation contractors and installs its own Smart-House Radiant Barrier, designed to reflect away 95 percent of the Sun's radiant energy.

On completion of a home, technicians check for air tightness using a machine that creates a vacuum in the house and enables computer calculations of the air exchanged, a measure of energy efficiency. When satisfied that the house has been built to its specifications, the company provides a guarantee that the home will use only a specified number of kilowatt hours yearly. A separate meter is installed to monitor and verify the energy use by the heating/cooling system. The system is applicable, with modifications, to existing homes as well as new structures.

Smart-House and GWS teamed up in 1982 and since then have effected a number of advancements in the system, such as the use of a computerized infiltrometer to verify air tightness, and the introduction of duct sealing and coating the underside of a roof with low emissivity paint in insulating existing homes. The GWS/Smart-House network has expanded considerably over the years; there are now 15 active centers in North Carolina, South Carolina, Oklahoma and Florida.

™ Guaranteed Watt Savers is a trademark of Guaranteed Watt Savers System, Inc.

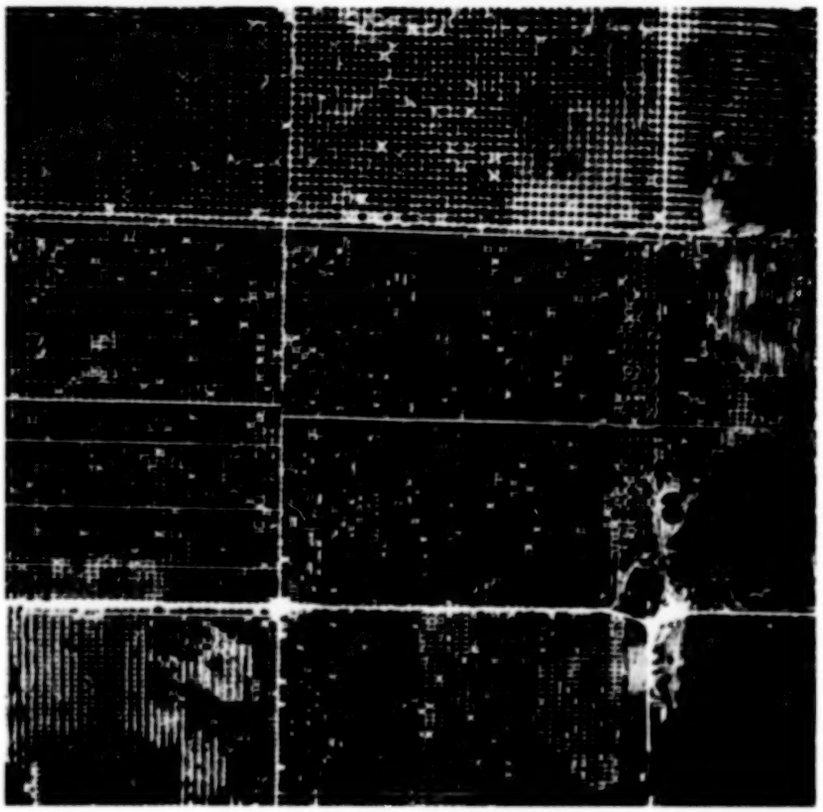
# Citrus Inventory

Fifteen years ago, Florida's Charlotte County appraised the value of its citrus groves by physically counting every individual tree on its 8,000 acres of groves. It took seven months if all went smoothly, and it was costly. Now the county has 25,000 acres, but it can do the job more economically in less than seven weeks, thanks to infusions of aerospace technology over a period of more than a decade.

The application of advanced technology to citrus grove mapping began in 1982 when Charlotte County Property Appraiser Oliver Lowe, looking for a faster, more economical way of appraising citrus groves, adapted an aerial color infrared (CIR) mapping system originally developed by Kennedy Space Center (KSC), to the job. This system enabled more accurate property valuations while reducing the county's appraisal costs. At **right** is a sample of a CIR aerial photo from which analysts can extract a great deal of information; it shows, for example, areas where trees were destroyed by insects, were replanted but are not yet fully productive, and other trees that are dead or damaged and therefore should not be counted as income producing property.

Subsequently, Charlotte County enlisted the aid of Dr. Carlos H. Blazquez of the University of Florida's Citrus Research and Education Center (CREC). Blazquez in turn sought KSC's help in advancing the technology. That led to joint KSC/CREC development of a dual video system consisting of paired color video cameras connected to side-by-side monitors; this made it possible to view images of the same area simultaneously and detect changes that occurred from one year to the next.

The Florida State Department of Revenue became interested in the Charlotte County appraisal technique and proposed another advancement: an image analysis system, based on NASA technology, that could automatically survey and photointerpret grove images. KSC's Technology Transfer Office awarded a contract to Dr. Blazquez to adapt a prototype system that would automatically count trees and report a total of trees for a block or grove. Subsequently, NASA, Charlotte County and five other Florida counties co-funded a technology demonstration of a computerized tree-counting system. The technology was successfully demonstrated in 1992 and in 1993 it became operational in Charlotte County.



According to Charlotte County officials, the CIR/image analysis system offers advantages in time savings, reduced equipment and maintenance costs, availability of permanent historical records, accurate tree counts and dollar savings to taxpayers. The system has potential beyond citrus grove valuation; the officials concluded "We have every reason to believe that the concept may be applied successfully to larger acreages and to crops other than citrus."

# A Personal Storm Warning Service

Among technology transfers that contribute to enhanced public safety is a family of affordable, general use lightning detectors

Each year in the United States more people are killed or injured by lightning than by tornadoes, floods and hurricanes combined. Lightning detection systems operated by government agencies, utilities and other businesses provide storm warnings, but their information is not readily available to the general public; it typically covers a broad region rather than a specific locale and reaches the public through radio and TV reports an hour or so after the observations are made.

However, there is now available a low-cost personal lightning detector that offers a significant safety advantage in immediate, localized warning of dangerous conditions. It is a valuable aid to business owners, private flyers, boaters, golfers, homeowners and millions of others who would like to know when it is prudent to stop outdoor activities and find shelter, or when to shut down sensitive equipment that could be damaged by lightning, or how to avoid costly liability suits by providing adequate warnings to employees and clients.

Through a family of portable detectors developed by Airborne Research Associates (ARA), Weston, Massachusetts, a user can get information on lightning presence and storm intensity allowing him to determine instantaneously whether ominous-looking clouds are dangerous, with as much as 30 minutes warning.

Now commercially available, these detectors had their origins in an early 1980s NASA project involving Space Shuttle tests of an optical lightning detection technique proposed by Professor Bernard Vonnegut of the State University of New York at Albany. Two decades of research had convinced Vonnegut that optical detection offered significant advantages over then-existing radio wave detectors. For one thing, optical signals are static-free and insensitive to man-made noise, thus can work close to machinery or within metal structures, such as the Shuttle Orbiter. For another, optical detection can provide directional information on which clouds contain lightning.

On three Space Shuttle missions in 1981-83, astronauts were able to observe and record lightning strikes within clouds far below them in broad daylight as well as at night (normally intracloud lightning flashes are not visible in daytime). The project, conducted by Marshall Space Flight Center, utilized a simple solar cell sensor and amplifier, a tape recorder and a movie camera. The sensor reacted to changes in light intensity. Whenever lightning flashed within the field of view, it produced a signal that was recorded as a click on the tape recorder. Night movies verified that the clicks were actual lightning flashes.

Dr. Ralph Markson, founder and president of ARA, became a participant in the NASA experiment when he was awarded a contract to test the camera system — called NOSL, for Nighttime/Daytime Optical Survey of Lightning — in an aircraft before it was flown on the Shuttle. In tests at Socorro, New Mexico, Markson was impressed by the system's ability to distinguish among developing clouds and determine which were the lightning-laden thunderstorm clouds. "I realized then," he says, "that this technology made it possible to develop a small, portable, inexpensive yet highly reliable lightning detector for public use."

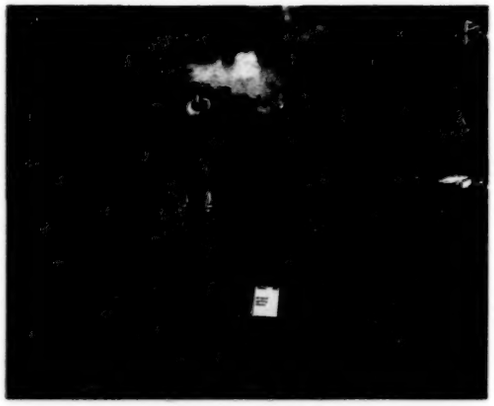
In the late 1980s, Markson used the NASA technology to develop a simple, hand-held optical lightning detector. After testing a prototype on the major golf tours of the Professional Golf Association, ARA refined the design and began marketing the M-10 detector in 1990. The device is simply pointed toward a cloud and it detects invisible intracloud lightning by sensing subtle changes in light intensity; it advises of lightning presence by a "beep." The M-10 features an electric field change detector so that occasional light reflections — which might trigger an optical-only detector — do not produce false alarms; the beep sounds only when the optical and field change signals occur simultaneously.

In 1993, ARA introduced a companion system, the P-10, which offers omni-directional warning; it is simply an M-10 encased in a housing with a conical mirror so that the system can guard all directions at once. An adjustable sensitivity control allows selection of the distance where lightning is observed.

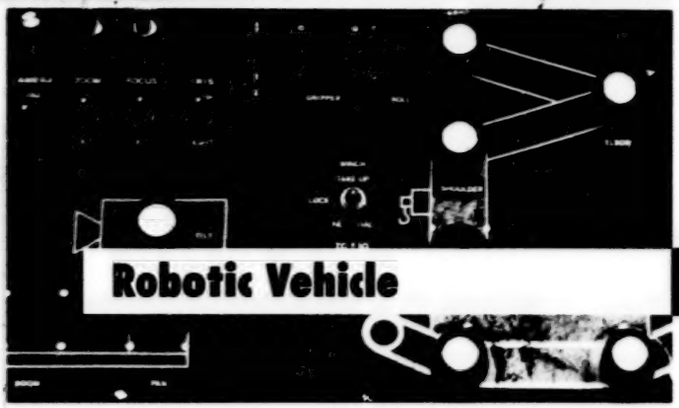
By the end of 1993, ARA had sold about 1,000 M-10s, mostly to golf courses. But the $600 cost was too expensive for most individuals, and industrial users wanted a full-time AC-powered system rather than the battery power of the M-10. So, in 1994, ARA introduced some new members of the family.

The newest consumer product is the M-2, an advanced version equipped with a ratemeter that, by measuring the lightning strikes per minute, provides a reading of storm intensity, allowing the user to decide whether clouds are indeed dangerous. For the industrial user, ARA has introduced the F-10, which essentially turns the P-10 into an AC-powered base station; the sensor section is housed within a transparent, waterproof casing for permanent installation on the roof of a building, connected to a control/display unit within the building that provides audible and light signals when lightning is detected.

Coming up in the near future is ARA's most advanced model, the F-20, which will provide the distance to each lightning flash, storm intensity and relays that can trigger alarms or automatically disconnect equipment that is sensitive to lightning.



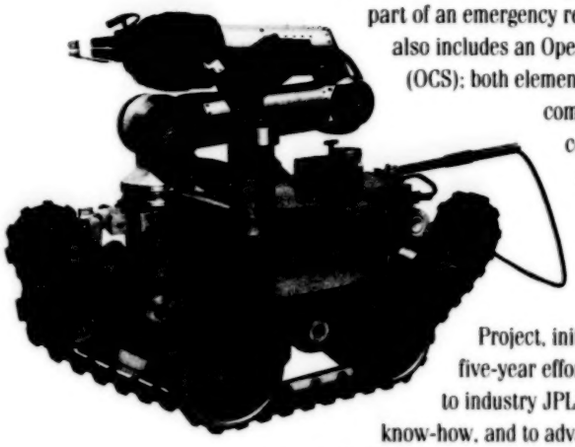
***Above,** a golfer practices putting, secure in the knowledge that his M-10 personal lightning detector (foreground) will signal a "beeping" warning of imminent storm danger. **At left,** a larger F-10 detector guards a multi-field municipal park whose tall trees often mask approaching storms until they are directly overhead; the F-10 sends audible and light warnings to baseball, softball and tennis players when lightning presence is detected.*



# Robotic Vehicle

Public Safety

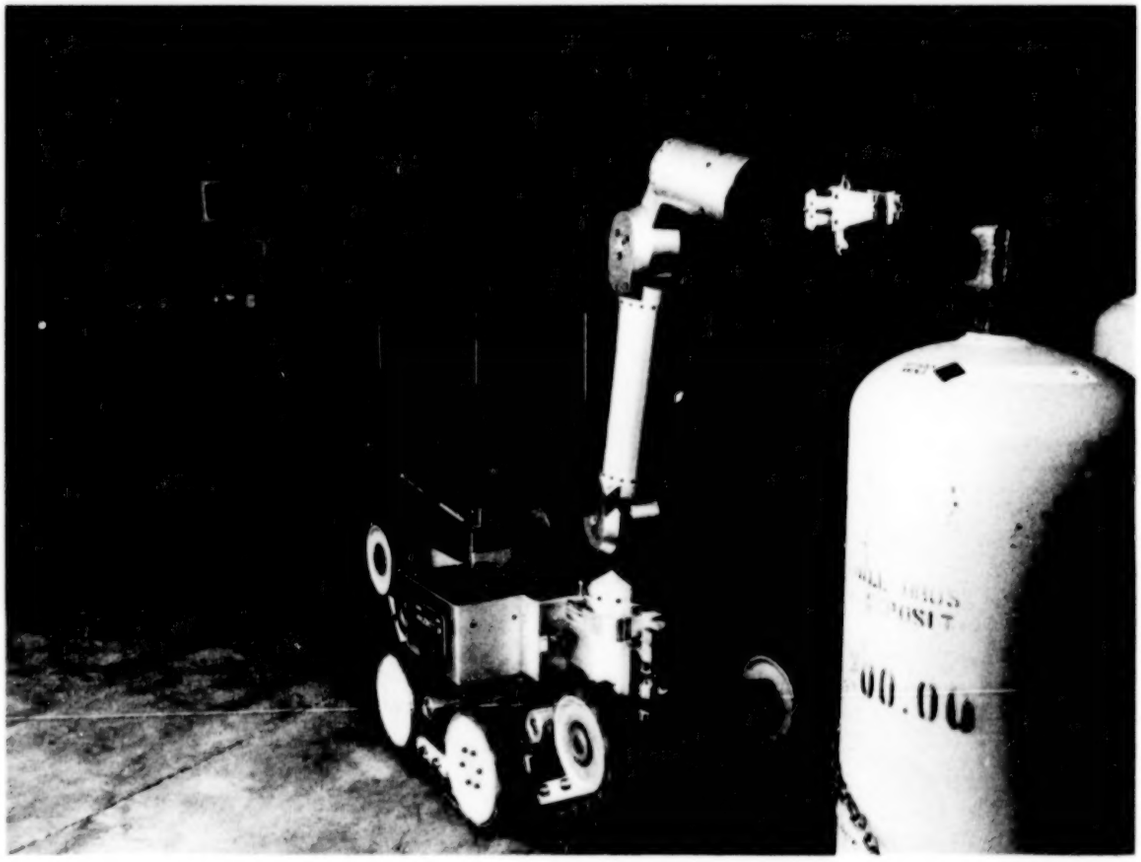
**Below** is HAZBOT III, a prototype teleoperated mobile robot designed for response to emergencies involving hazardous materials. Developed by Jet Propulsion Laboratory (JPL), HAZBOT III is part of an emergency response system that also includes an Operator Control Station (OCS); both elements have independent computer systems that communicate with each other via a tether.



The system is a product of a NASA-funded Emergency Response Robotics Project, initiated by NASA as a five-year effort to apply and transfer to industry JPL's extensive robotic know-how, and to advance robotics technology for HAZMAT, nuclear, mining, law enforcement and other applications.

Teleoperated robots can contribute significantly to reducing human injury levels by performing hazardous tasks that would otherwise be handled by humans. An example is shown **below**, where HAZBOT III is sensing leaks from a cylinder of anhydrous ammonia under the supervision of Jerry Collins of the JPL Fire Department/HAZMAT Team (in actual use, Collins would operate the robot from a safe location away from the incident site).

JPL did not develop HAZBOT III from scratch, but used as a developmental departure point a commercially available ANDROS Mark V-A robot manufactured by REMOTEC®, Inc., Oak Ridge, Tennessee, a segment of Westinghouse Electronic Systems Group. In the course of developing the emergency response system, JPL extensively redesigned its ANDROS and added features based on feedback from JPL Fire Department personnel who tested the vehicle.



HAZBOT III has exceptional mobility, contributed by its tanklike track drive with special articulated front and rear sections, which allow the vehicle to climb stairs and move over obstacles as well as negotiate rough terrain. On-board batteries give the vehicle enough power for missions longer than three hours.

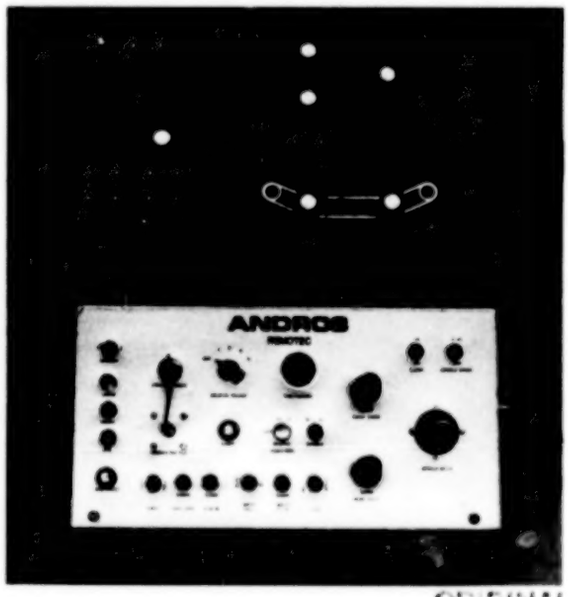
A significant feature is the vehicle's unique design for safe operation within a combustible atmosphere; it employs solid state electronics and brushless DC motors to bar electrical arcing, and the chassis/manipulator design allows for positive pressurization of all areas containing electronics and motors so combustible gases cannot enter.

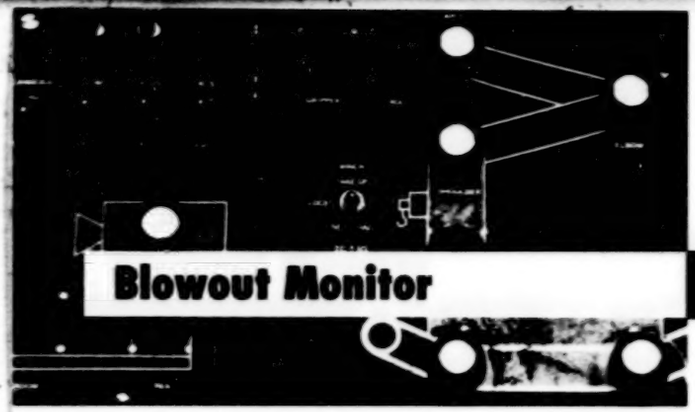
Among other features are the six-degree-of-freedom manipulator with a five-foot reach and a 30-pound lift capability; a 30-pound squeeze force parallel jaw gripper; two video cameras, one for general viewing and navigation, the other on the arm's wrist for manipulation/grasping; a gas sensor built into the manipulator forearm; custom tools for unlocking and opening doors; and a small winch that serves a variety of mission functions.

*REMOTEC is a registered trademark of REMOTEC, Inc.

A major feature added was a new control panel, shown **above** being operated by Rick Welch, task manager of the Emergency Response Robotics Project. The original ANDROS control panel consisted of a simple bank of toggle switches, one to control each action of the robot, which made complex manipulation tasks difficult and tedious. The new, simplified control panel (shown **at right** above its predecessor) uses spring-loaded potentiometers placed on a side-view graphic of the robot. If a potentiometer is rotated clockwise, the corresponding joint moves in that direction; the potentiometers also provide velocity control for the different robot actions.

The JPL project achieved its first technology transfer to industry when REMOTEC reported to JPL that it was adopting some of the design concepts developed for HAZBOT III, in particular the control panel. Sammy L. Jones, field projects manager for REMOTEC, reported to JPL that "We anticipate this design change will enhance our operator control station and make our ANDROS vehicle easier and safer to operate." REMOTEC and JPL are looking at other technology developed in the Emergency Response Robotics Project that could be transferred.





# Blowout Monitor

Public Safety

Oil drilling rigs can pose hazards to human life, property and the environment if they are not properly monitored for possible blowouts. An oil well blowout results from uncontrolled subsurface flows known as "kicks," which are caused by oil, gas or water entering the wellbore and traveling up the well casing to the surface.

A petroleum industry goal is developing a method for predicting a blowout and advising oil rig crews how to correct such a situation. The Drilling Engineering Association (DEA), a cooperative of 11 oil/gas service companies, is funding a project conducted by Tracor Applied Sciences, Austin, Texas for development of a Well Site Advisor (WSA), a PC-based expert system for training oil rig personnel in taking well control actions. With the help of a NASA computer program called CLIPS, Baker Hughes INTEQ, Houston, Texas is developing a Unix-based version of the WSA for use at the rigsite.

Originally developed by Johnson Space Center, CLIPS is a software shell for developing expert systems. It is designed to permit research, development and delivery of artificial intelligence on conventional computers. A collection of rules is set up and, as facts become known, these rules are applied. The versatility and power of CLIPS has made it a valuable research tool for applications such as INTEQ's WSA, which provides the capability to accurately process, predict and interpret well data in a real time mode.

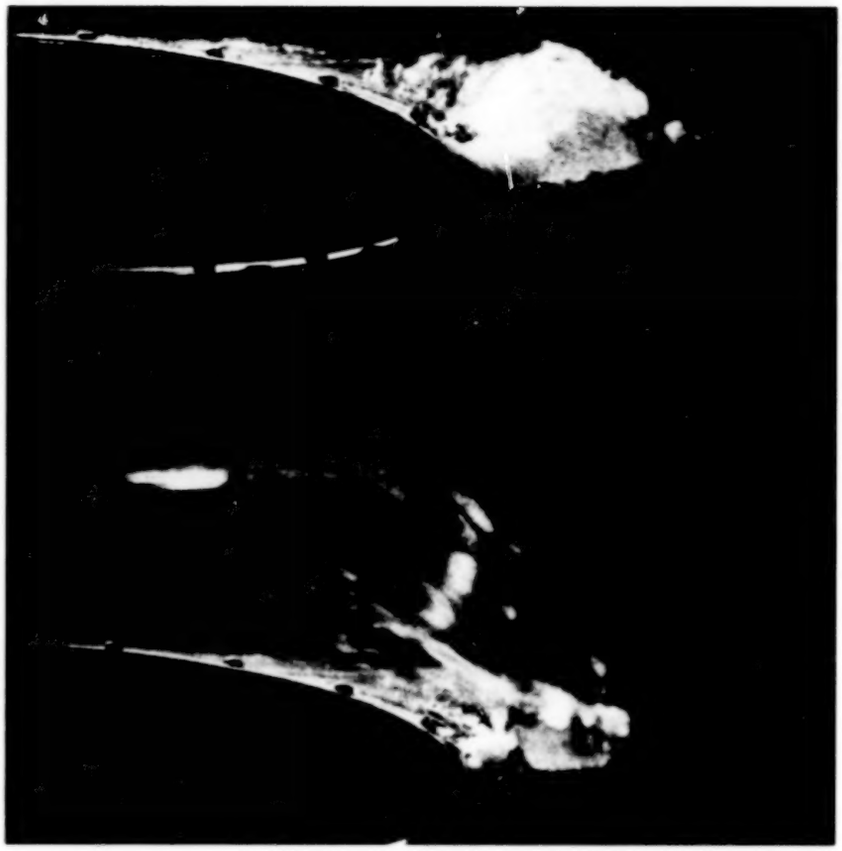
By means of electronic sensors, a kick is tracked as it moves upward in the drilling system. Using mathematical data from the sensors and rules set up by industry experts as part of the DEA project, the embedded CLIPS portion of the WSA attempts to predict whether the kick has the strength to reach the surface and to diagnose the probable cause of the problem when actual conditions do not match predictions.

The accumulated well site data is used by CLIPS to provide a list of probable causes. Then CLIPS starts a diagnostic session of questions and answers to develop more refined calculations of possible situations. The WSA displays the results coupled with the rules of logic CLIPS used to obtain them; **at left**, a drill byte operator is reviewing the results to decide which scenarios best matches a current situation.

CLIPS was provided to INTEQ by COSMIC®, NASA's Computer Software Management and Information Center (see page 128). Located at the University of Georgia (Athens), COSMIC routinely makes available to industrial and other clients government developed computer programs that have secondary utility.

®COSMIC is a registered trademark of the National Aeronautics and Space Administration

# Ice Protection



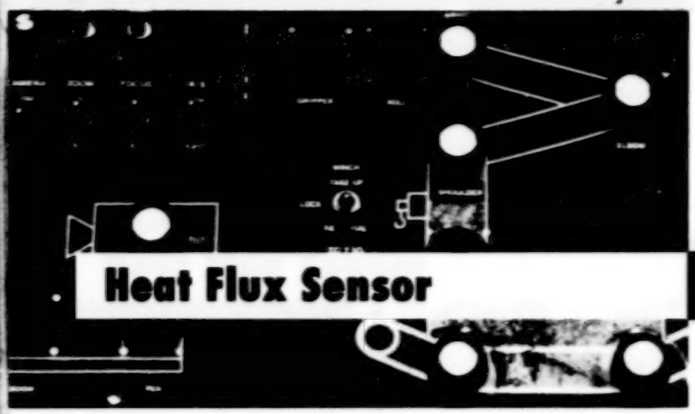
Ice buildup — or "accretion" — on the wings of aircraft represents a potential source of accidents or damage to airplanes. Therefore any innovation that promises greater deicing efficiency is of special interest to airline operators, the military services, aircraft manufacturers and public safety agencies.

Now commercially available is a new ice removal system designed to overcome some of the limitations of existing electro-thermal deicers. Originally developed by Ames Research Center, the system was refined by DNE Technologies, Inc., Wallingford, Connecticut and is being marketed by DNE under a NASA license.

The system employs a technique known as expulsive ice shedding. Expulsive separation "blankets" are applied to an aerodynamic surface subject to ice accretion — a wing, helicopter rotor or engine inlet, for example — and the blankets protect the surface by mechanically expelling the ice periodically. The force to expel the ice is developed magnetically by passing a strong direct current pulse through conductors embedded in the blanket; this causes an explosive expansion of the blanket that ejects the ice on the aerodynamic surface.

"Expulsive blankets have the ability to cleanly shed all forms of meteorological ice at virtually any thickness," DNE officials say. The system has been proved effective in a variety of icing tunnels and in natural icing conditions. The sequential photos show a DNE tunnel test of the expulsive separation system on an ice-covered aircraft wing segment. In the **top photo**, the system has just been activated; in the **lower photo**, taken less than a millisecond later, most of the ice has been pulverized and ejected.

DNE substantially modified the Ames technology to make the system commercially viable. Among refinements are extended service life, achieved by controlling internal conductor deformation in a manner that virtually eliminates conductor metal fatigue; improvement of blanket efficiency by better conversion of electrical energy to mechanical energy; blanket level redundancy; and a sharp reduction in the size and weight of the blanket's electronic controllers. The laboratory development system of 1988 needed a power supply that weighed nearly 40 pounds for eight square feet of blanket; the advanced system's power supply drives 16 square feet of blanket and weighs less than 10 pounds.



# Heat Flux Sensor

Public Safety

**Shown below** is a size comparison view of a new Heat Flux Microsensor developed by Vatell Corporation, Christiansburg, Virginia. It was developed under a Small Business Innovation Research contract as part of the NASA/Department of Defense National Aero-Space Plane (NASP) hypersonic research program.

The development was intended to meet a need for an advanced heat flux gage capable of operating durably and reliably in very high temperature, high heat flux environments in such applications as gas turbine blades, hypersonic combustion chambers, rocket nozzles and atmospheric reentry panels.

Vatell used the NASP technology as a departure point for development of a line of commercially available sensors that measure heat flux (the rate of heat energy flowing into and out of a surface) and at the same time provide readings on the temperature of the surface. The Heat Flux Microsensor is designed for heat transfer measurements under adverse environmental conditions or where exceptional ruggedness is a requirement.

Vatell's microsensors are fabricated with thin film layers of conducting and insulating material applied by a sputtering process; the total thickness of all layers is about two microns, so thin that the gages cause negligible flow disruption. They are available on ceramic or metal substrates, in standard or custom designs.

Major advantages, in addition to simultaneous measurement of both heat flux and surface temperature, include response to heat flux in less than 10 microseconds and the ability to withstand temperatures up to 1200 degrees Centigrade.

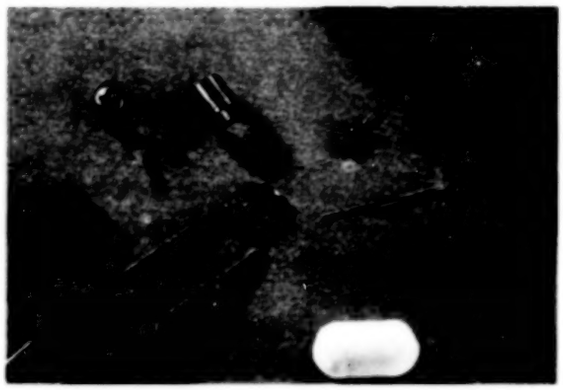
The Vatell microsensor has a wide range of potential applications in and beyond aerospace operations, including high speed aerodynamics, supersonic combustion, boiling heat transfer, flame dynamics, blade cooling, thermal property measurement, mass flow measurement and blood perfusion measurement.

# Heat Stress Monitor

In the U.S. there are some 8,000 members of hazardous materials (HAZMAT) response teams who must frequently wear full body protection suits. There are many thousands of others, such as firefighters, divers and nuclear facility technicians, who must wear similar protective gear. The equipment is heavy and cumbersome, and it causes marked elevation of body temperatures, which at best reduces the effectiveness of the worker and at worst can lead to heat stress and serious injury.

Human Technologies, Inc. (HTI), St. Petersburg, Florida, saw a need for a means of measuring body core temperatures of people subjected to heat stress environments and providing a warning to the wearer of protective gear and his/her command post. The company manufactures a spinoff system known as CorTemp — developed by Johns Hopkins Applied Physics Laboratory for NASA physiological monitoring — that is already in wide use in medical applications; HTI felt that, with modification and refinement, CorTemp could provide the basis for a body temperature monitoring/alarm system.

In 1993, HTI launched a HAZMAT Stress Alert Program to test the CorTemp System in actual heat stress environments and acquire data on what further development is needed to make it a fully effective safety and communications tool. The program kicked off with a series of tests conducted by the St. Petersburg Fire Department,

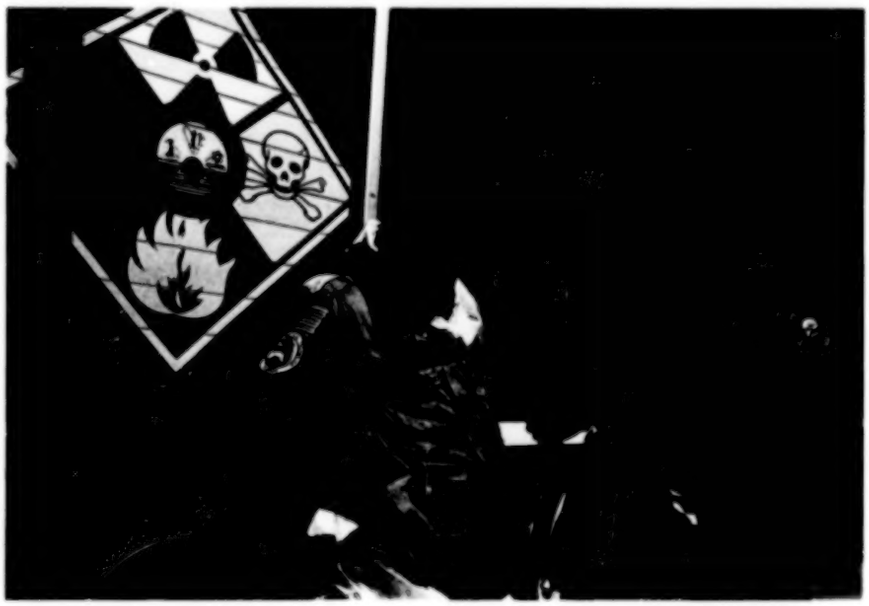


which is part of the Pinellas County Hazardous Materials Response Team.

The CorTemp System, encased in a three-quarter-inch ingestible capsule, includes a mini-thermometer, a miniature telemetry system, a microbattery and a temperature sensor; the capsule (white) is shown **above** with its tiny components. Taken as a pill, the capsule makes its way through the digestive system, continuously monitoring body temperature by means of the crystal quartz sensor. **Below,** a member of the St. Petersburg Fire Department is being helped into his HAZMAT gear; the CorTemp recorder is visible on his belt.

Through 1993, HTI had sold some 200 CorTemp systems to medical institutions, commercial firms and military services throughout the world; the system enjoyed a 100 percent success rate in some 12,000 ingestions.

In addition to the St. Petersburg HAZMAT tests, nine other HTI customers are using the CorTemp System for heat stress analysis and warning. Seven other organizations are investigating the potential of the system.



# Technology for the Sound of Music

An instrumental derivative of aerospace technology highlights spinoffs for consumer, home and recreational use

At first blush, guitars and helicopter rotors would seem to have little in common. There is a connection, though: they both vibrate. And that connection proved to be the springboard that launched a most impressive aerospace technology transfer: the development of a line of acoustic guitars and the establishment of a company to market them, a company that has mushroomed over a quarter-century into the world's largest distributor of musical products.

The genesis of the story goes all the way back to 1945 when a 26-year-old aerospace engineer named Charles H. Kaman left his job with a helicopter manufacturer, started Kaman Aerospace Company and began producing helicopters of his own design. Known for their exceptional stability/controllability and for a variety of technological innovations, Kaman's machines quickly moved the company into the upper ranks among the nation's helicopter manufacturers and brought large-scale contracts from the Department of Defense.

But in the early 1960s, in one of those periodic recessions that are endemic to the aerospace/defense industry, Kaman Aircraft saw its largest contract cancelled and the prospects of deep cutbacks in other defense work. The company was forced to diversify into other areas and it was natural that Charles Kaman, a professional caliber guitarist, should turn to musical instruments; he saw that aerospace technology offered a number of ways of substantially improving the sound quality of acoustic guitars.

That's where the vibration connection comes in. Says Charles Kaman:

"In helicopters, the engineers spend all their time trying to figure out how to remove vibration. And to build a guitar you spend your time trying to figure out how to put vibration in. But vibration is vibration. And we had materials coming out of aircraft development that made a vastly better guitar."

A helicopter's rotor system, with thousands of moving parts, is highly susceptible to vibration. For rotor efficiency, vibration must be reduced, or "dampened." NASA, the military services and contractors like Kaman Aircraft had spent years of research toward that end and Charles Kaman turned this vibration dampening technology around and applied it to enhance vibration and thereby produce a guitar with a superior sound.

Kaman and his team of engineers put the quest for sound excellence on a scientific basis, using special vibration analysis equipment patterned on aerospace technology. From two years of vibration analysis, there emerged an innovative, bowl-like guitar that Kaman considered the ideal shape for full, rich and constant tone throughout the instrument's range.

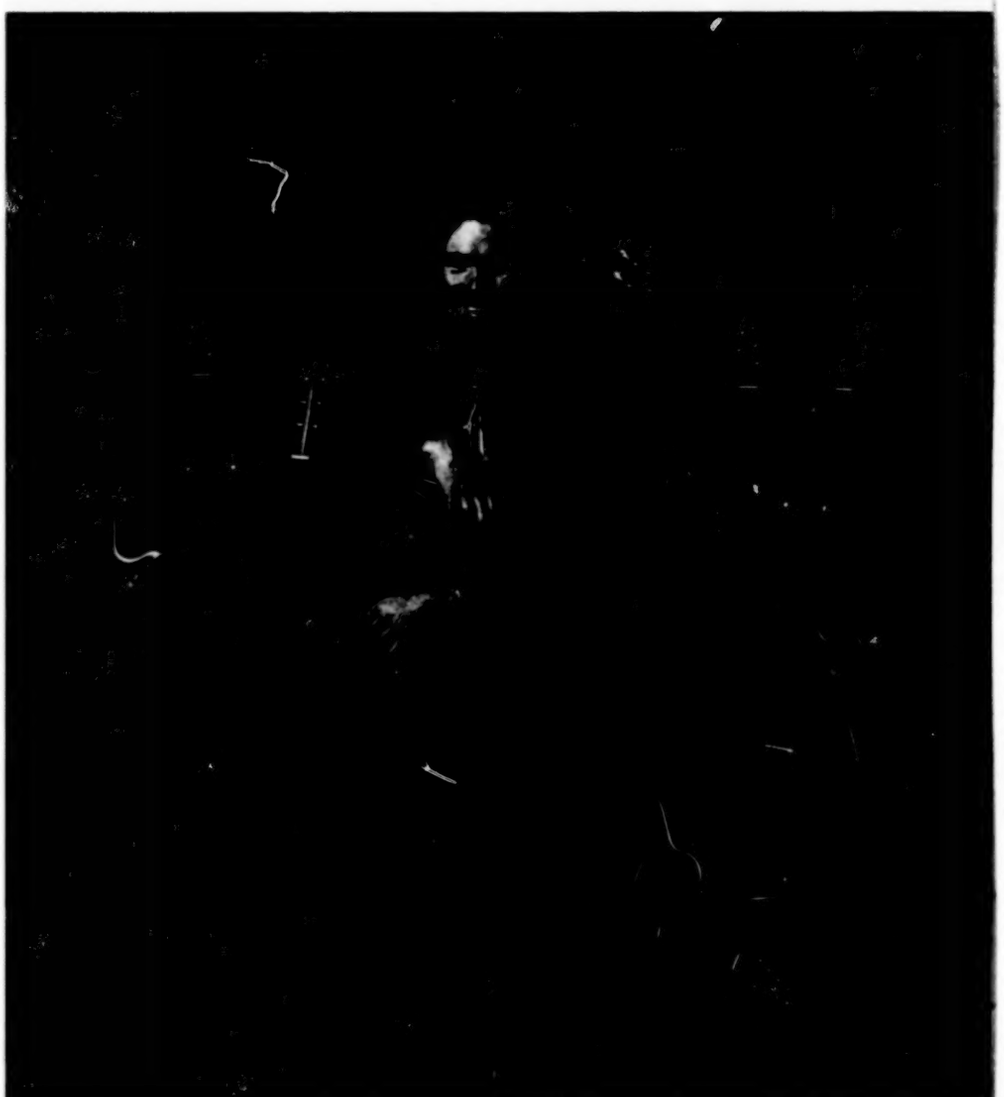
Since wooden guitars sometimes crack, Kaman borrowed again from aerospace research on composite materials for rotor blades and decided on fiberglass for the guitar's surface; it was almost impossible to break, easier to get than rosewood (the traditional material for fine guitars), and it offered advantages in shaping, strength, sound and producibility.

For manufacturing the guitars, Kaman made still another trip to the aerospace technology well and adapted aircraft manufacturing techniques, such as the use of jigs and fixtures, to guitar production. This reduced labor requirements and assured effective quality/cost control in the manufacturing process.

The new guitar got its name when jazz great Charlie Byrd tried out a Kaman instrument and pronounced that it "deserved an ovation." The Ovation® Roundback guitar it became, and Kaman formed Ovation Instruments, Inc. as a subsidiary company.

Ovation guitars were an instant success. Initially, the company produced guitars for the top of the market, mostly for professional entertainers. Later, the advantages of aerospace-derived manufacturing techniques enabled the company to move into the lower-priced fields. Today, Ovation guitars own a large percentage of the acoustic guitar market.

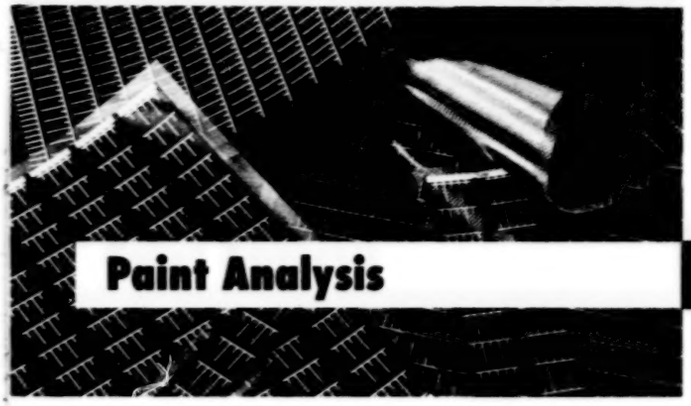
The parent company — now known as Kaman Corporation, Bloomfield, Connecticut —has expanded into a widely-diversified Fortune 500 company with annual sales approaching $800 million. Charles H. Kaman continues as its chairman, but he also follows closely the activities of the music subsidiary.



*C. W. "Bill" Kaman, II, president of Kaman Music Corporation, shows off an original Ovation Roundback guitar (center) and some of the company's 1994 line of musical instruments. Bill Kaman is the son of Charles H. Kaman, whose development of a line of guitars based on aerospace technology spawned what is now the world's largest distributor of musical products.*

Ovation Instruments is now a part of a big, multinational manufacturing and distribution entity known as Kaman Music Corporation (KMC), also headquartered in Bloomfield and headed by C. W. "Bill" Kaman, II, son of the founder. KMC has four manufacturing divisions, three distribution divisions and an international marketing group whose combined operations generate annual sales of $100 million.

® Ovation is a registered trademark of Kaman Corporation.



# Paint Analysis

Consumer/Home/Recreation

The Painting Conservation Laboratory of The Cleveland Museum of Art (CMA), Cleveland, Ohio is responsible for the preservation and restoration of the museum's internationally renowned collection of paintings, some of which date to the 13th century. The laboratory often conducts technical research to analyze an artist's technique or to produce other information important to conservators and art historians; on occasion, analysis provides vital clues where there is a question of authenticity.

For artworks with multiple, complex layers of paint, the laboratory conducts "cross-sectional analysis," which involves microscopic scanning of a cross-section of a paint chip for study of the various layers prior to undertaking a restoration or maintenance treatment — for example, in deciding whether a particular paint layer is original or a prior restoration.

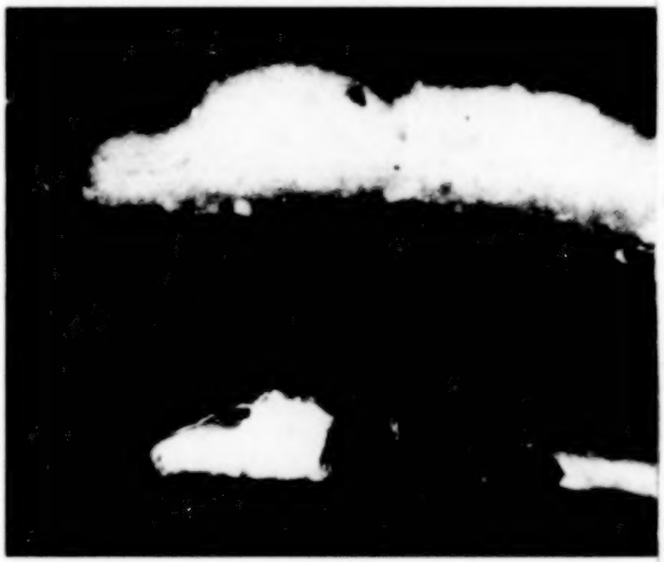
A cross-section provides a chronology of the artist's working method. Seemingly a flat coating on a canvas, a painting is actually a complex three-dimensional structure, created as the artist builds up layers of paint to develop subtle effects of tone, color and surface texture. Through cross-section viewing at high magnification under a variety of lighting conditions, conservators can distinguish original from restoration layers, determine the composition of individual layers, and acquire other information pertinent to conservation processes.

A problem relative to cross-sectional analysis is the method of preparing the sample, traditionally an extremely time-consuming manual process that often produces unsatisfactory samples. Samples are rarely flat enough for proper viewing at higher magnifications; surfaces are frequently marked by scratches; and the resulting cross-sections are unlikely to be of a quality suitable for publishable photography.

Looking for a better way, CMA and Lewis Research Center collaborated on a research project in which the NASA center's expertise and technology were applied to development of a new method of preparing cross-sectional samples.

The research was conducted by Lewis' Metallography Laboratory, which was provided paint sample particles from a 19th century portrait. After a number of experiments, the laboratory devised a two-step automated method that produces intact, perfectly flat, polished paint cross-sections, for photomicrography or for use in analysis techniques such as electron microscope scanning and biological staining. Lewis used a sophisticated, microprocessor-controlled grinding and polishing machine normally employed in preparation of exotic samples for aerospace research, but the technique is readily adaptable to use with less sophisticated grinding and polishing equipment.

In the **upper photo** is a highly-magnified cross section of a paint chip prepared by the traditional method, with the layers poorly defined. In the **bottom photo** is the same cross section photographed after grinding and polishing by the Lewis-developed method; the sample is perfectly flat and its layers are clearly defined.

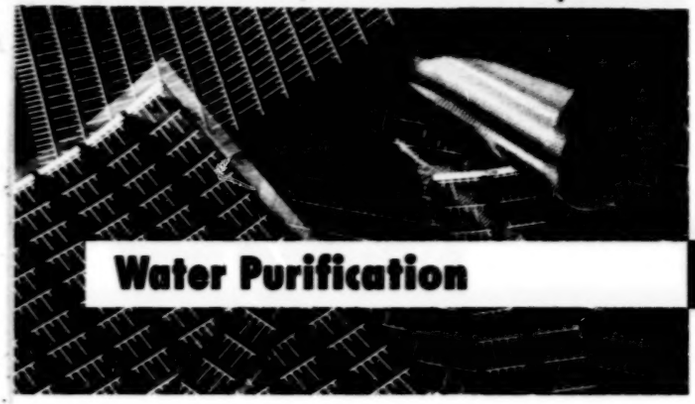


ORIGINAL PAGE
COLOR PHOTOGRAPH

**Above** are the Lewis/CMA participants in the research project, from left, Marcia Steele, CMA; Todd Leonhardt, a Lewis metallographer who devised the automated sample preparation process; William J. Waters, Lewis; Christina Currie, CMA; and Anthony Ratajczak, Technology Transfer Officer at Lewis Research Center. In the same photo, on the black tray atop the desk, is a small cylinder containing an encapsulated paint chip, its profile visible on the console screen; technicians use this equipment to identify and photograph specific segments of the sample for analysis.

**At right**, researchers are examining the composition of individual paint layers; Lewis' James Smith (at the console) is flanked by CMA's Steele and Currie. The equipment pictured, normally used for qualitative evaluation of aerospace metals and ceramics, provides very high magnifications for investigation of the microstructure of a material.

The automated sample preparation process has been used successfully on a wide range of CMA paintings. The museum and Lewis Research Center are exploring other avenues wherein NASA technology might be employed to the advantage of art museums.



# Water Purification

Consumer/Home/Recreation

**Shown below** is a Vision™ Catalyst Purifier, a hybrid catalytic/ion dispersal water purification system manufactured by Fountainhead Technologies, Inc., Providence, Rhode Island. The vision system employs the basic technology developed by NASA for purifying spacecraft drinking water, but Fountainhead additionally uses a patented "erosion" technique that differs from the approaches employed in many spinoffs from the NASA technology.

For the Apollo spacecraft, Johnson Space Center developed an advanced system for supplying purified water for the three-man Apollo crew for missions up to two weeks (see page 86). This tiny, compact system, based on use of an electrode to generate ions, offered an alternative to use of chemicals for water purification, hence found broad spinoff application.

The Vision purifier kills bacteria, viruses and algae by a process the company refers to as "catalytic conversion." A cartridge contains a silver-impregnated alumina bed that has a very large surface area, roughly the equivalent of three acres. This catalyst bed converts the available oxygen in a pool of water to its most oxidative state, which kills more than 99 percent of the bacteria within five seconds (15 times faster than chlorine, the company claims).

In addition, the cartridge releases into the pool low levels of ionic silver and copper through a controlled process of erosion. The flow of water becomes electrochemically active due to the presence of dissimilar metals within the cartridge, so no electricity is required.

The process of erosion delivers residual sanitizer into the pool, which further inhibits bacteria. The volume of ions released is automatically limited by the design of the cartridge and it is extremely low, well within the Environmental Protection Agency's standards for drinking water. Fountainhead Technologies produces Vision Catalyst Purifiers in several sizes for use in recreational pools, spas and other applications.

™ Vision is a trademark of Fountainhead Technologies, Inc.

# Windsurfer Fin

**At right**, windsurfing sailor Cort Larned is "taking air" (jumping off the wave) with the help of a new VooDoo™ Advanced Windsurfing Fin. Produced and marketed by Twist Wing International, Toronto, Ontario, the fin is based on NASA airfoil technology developed by Langley Research Center.

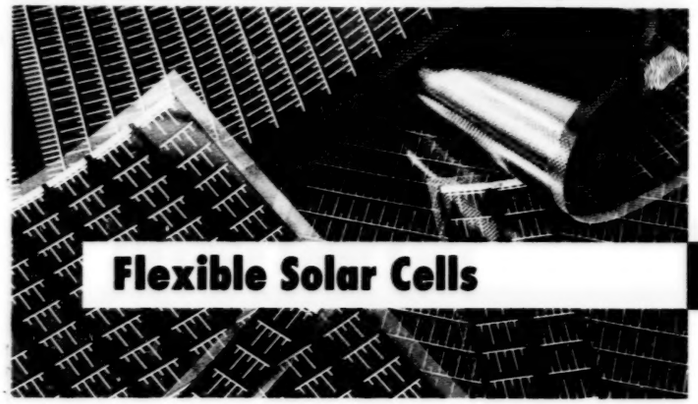
In researching the design of a new line of windsurfing fins, company engineers found a pertinent NASA technical report that detailed a Langley wind tunnel investigation of a variable camber and twist aircraft wing. Camber is the curve of an airfoil cross-section; for the Langley research, the test wing incorporated moveable segments at the wing's leading and trailing edges whose movements changed the camber of the wing. The technical report stated: "The result of the investigation shows that, when properly incorporated, variable camber and twist can effectively reduce the drag of a thin low-aspect-ratio wing over a wide range of lift coefficients."

Since the hydrofoil fin is a close relative of an airfoil, the NASA report offered a way to substantially improve the performance of windsurfing fins. Twist Wing International adapted the NASA technology to the VooDoo design and identified materials that would provide the desired twist characteristics and could be used in volume production. The VooDoo fin is made of composite materials with two distinct aspects: a rigid internal spar and a flexible polymer exterior coating. Says Twist Wing vice president Keith Pires:

"The design of our products enables the windsurfing fin to twist at the trailing edge of the foil with progressively more pronounced twist toward the tip. In a series of arms-length tests by professional sailors in Lago di Garda, Italy, it was determined that the capabilities of VooDoo fins dramatically improved upwind performance in comparison to similar windsurfing fins of standard construction (having limited or no twist)." In addition, says Pires, composite construction makes the fin exceptionally durable.

In designing the VooDoo fins, Twist Wing selects a NASA foil section and mathematically models it, using ALIAS computer design software, which allows interrogation of the design to determine aspect ratio, camber and volume of the hydrofoil. Critical tolerances are precisely controlled by computer-aided design and manufacturing tools. The digital information is then used to create precision metal tooling for volume production. VooDoo fins are being sold in the U.S., Canada, Mexico, the United Kingdom and Italy.

™VooDoo is a trademark of Twist Wing International.



# Flexible Solar Cells

Consumer/Home/Recreation

**At left below** are a number of solar cell "modules" produced by Iowa Thin Film Technologies, Inc., Ames, Iowa. They represent an advancement over the traditional solar cell for certain applications in that they are extremely light, can be rolled or folded and made to conform to curved surfaces, and are made of non-breakable materials for durability. The products and the company are spinoffs from research grants by NASA and the Department of Energy (DoE).

A module is a plastic strip coated with a thin film of photovoltaic silicon that collects solar energy for instant conversion into electricity. Lasers divide the thin film coating into smaller cells to build up voltage; Iowa Thin Film Technologies' modules can supply from .8 volts to 200 volts. The modules are fabricated by laser scribing and welding, and by screen printing on the plastic substrate as shown **below**.

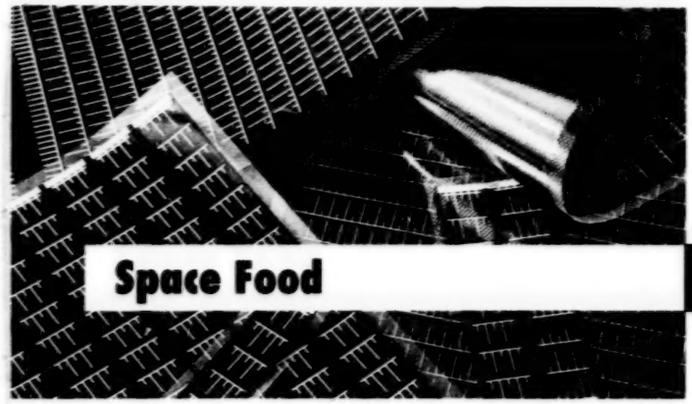
**At right** is a solar-powered model airplane built by the company to demonstrate the product. The cell modules mounted on the wing sections collect light from the Sun and convert it to electricity that drives the small motor and propeller atop the wing center section. The company is selling modules to model airplane enthusiasts through hobby catalogs.


Iowa Thin Film Technologies' principal products, however, are for use in applications currently served by batteries: as electrical supply for indoor advertising displays and as battery rechargers for recreational vehicles. The point-of-sale advertising modules use the ambient light in a store to power flashing lights or a motor in the advertising display. For the recreational vehicle application, the modules are incorporated in the rollout awning cover on the top side of the vehicle **(below)**: the light weight and flexibility of the cell modules make this application possible.

These applications represent only the beginning of a lengthy list of possibilities envisioned by company president Frank Jeffrey and co-founders Derrick Grimmer and Steve Martens. They see future use for the modules as power supplies for toys and educational kits; as battery chargers for electronic equipment, radios and computers, as well as recreational vehicles and boats; as energy suppliers for industrial safety equipment; in mobile communications systems; and for camping and emergency gear.

The development of flexible cells began in 1988 as a joint project of 3M Company, St. Paul, Minnesota and Iowa State University (Ames), working under a grant from the Iowa Department of Economic Development. When the grant expired, 3M physicists Jeffrey and Grimmer decided to leave the company and pursue further flexible solar cell research on their own; they moved to Ames, founded Iowa Thin Film Technologies and teamed with the Iowa State research team on a new project to explore advanced solar cell technology for space flight and consumer products. Working under a new contract with Lewis Research Center and DoE under the Small Business Innovation Research program, they generated the flexible solar cell technology and developed techniques for manufacturing the modules.

Looking to the future, Jeffrey, Grimmer and Martens believe that the technology has excellent long range potential for remote power applications in parts of Africa, the Middle East, India and China. They acknowledge that a further reduction in manufacturing costs will be needed for such applications, but they are starting now to get an early handle on product definition and marketing networks.



# Space Food

Consumer/Home/Recreation

In the early days of manned space flight, NASA provided basic squeeze-tube sustenance for the astronauts, food not particularly tasty but that was not considered a major problem due to the relatively short durations of Mercury (1961-63) and Gemini (1965-66) missions. But, planning for Apollo missions of up to 13 days and for later space stays of even longer duration, NASA wanted meals that were not only appetizing and nutritious but were also easily prepared and low in weight. The weight of the individual meal and whatever hardware was required to prepare it became a consideration because the Apollo spacecraft would have to carry meals for three astronauts for two weeks.

During the 1960s and into the 1970s, NASA conducted an extensive program of research into advanced types of space food, contracting with a number of food processing companies pursuing various approaches to the problem. One of the techniques developed was the freeze drying process, in which water is extracted from freshly cooked foods by dehydration at very low temperatures. Flavor is locked in by freeze drying the food and then sealing it in special pouches that block out moisture and oxygen, the principal causes of food deterioration. This makes it possible to store the food for long periods without refrigeration. Among the companies that have successfully commercialized the freeze drying technology is


Action Products International, Inc. (API), Ocala, Florida. Founded in 1977 as a garage industry by Judith Kaplan of Queens, New York, API (then known as Action Packets) acquired the NASA technology from a now-defunct company that had been a subcontractor to Whirlpool Corporation, St. Joseph, Michigan, one of the original developers of the NASA freeze drying process. API focuses on a special niche of the market: freeze dried snack food, including the first freeze-dried ice cream.

Today the company offers 22 varieties of Action Snacks™ and Adventure Foods, including several ice cream products, two types of yogurt, apples, sliced bananas, whole strawberries, fruit cocktail, french fries and the newest and most popular of the line, cheese pizza. The accompanying photos show some of API's products.

These foods are cooked, then quickly frozen to 40 degrees below zero Fahrenheit. The moisture is removed when the ice crystals formed by the freezing process are turned to vapor by slow heating in a vacuum chamber. The final product, according to API officials, retains 98 percent of the fresh food nutritional equivalent and weighs only 20 percent of its original weight.

API's main outlets for its products are about 2,000 museum and planetarium shops. Action Snacks are also sold at 11 NASA facilities, at space theme parks and at a number of corporate employee shops. The company also exports its products to Japan, England, Sweden, New Zealand, Germany, France, Hong Kong, Denmark and Italy. The one-time garage industry has grown into a 35,000 square foot facility on a 2 1/2 acre industrial site, and company sales run to several million dollars annually.

™ Action Snacks is a trademark of Action Products International, Inc.

# Reflective Packaging

Consumer/Home/Recreation

When things got a bit slow in commercial real estate, Richmond (Virginia) developer David Shea turned his developmental talents in another direction. He saw a market for superinsulated containers that would allow safer shipment of perishable products, and he saw a way of making them: by adapting NASA's radiant barrier technology.

Over the years NASA has developed a number of methods for protecting astronauts, instruments and on-board equipment in spacecraft subjected to temperatures that may range several hundred degrees above and below zero Fahrenheit. Among them is a highly effective radiation barrier, made of aluminized polymer film, that allowed Apollo astronauts to work in shirtsleeves inside the Apollo Command Module. The film barred — or held in — heat to maintain an even temperature in an environment where ordinary insulation would not have sufficed.

This technology has been employed on virtually all spacecraft, including unmanned spacecraft whose delicate instruments need protection from extremes of temperature. It has also spawned a broad variety of spinoff applications, from home insulation to candy wrappings to David Shea's new radiation-reflecting containers.

Beginning in November 1992, Shea set up a "laboratory" in his dining room and began experimenting with aluminized thermal reflective materials. "I used cans of beer and tried to keep them cold," he says. "After many, many attempts at package design, I found a way to make it work."

Shea formed a company — Radiant Technologies, Inc. of Richmond — to market the barrier material and found other companies to supply him the component materials. His barrier is usually made of layers of aluminized foil that serve as liners for reusable shipping bags, cartons or pallet covers. The packaging reflects outside heat away from the product inside the container. As a product demonstration, Shea arranged with the Department of Defense to send 12 very large bags of ice cream to Sun-baked Somalia for U.S. troops' Fourth of July celebration. The bags were 120 hours en route but the ice cream arrived frozen.

Radiant Technologies' business is beginning to take off. The company's initial product line, in addition to the aluminized shipping bags, includes pallet covers, food cart covers **(photo)** and medical bags. The pallet covers, being used by major food distributors, are large, nylon coverings with a layer of radiant barrier material between the inner and outer surfaces; they are used to seal entire palletized loads. The medical bags are soft, "tote" style bags, light and strong, very effective for moving temperatur sensitive medical products such as tissues (a shipment of ostrich eye lenses was brought to the U.S. from Israel). Shea's company is also developing a new line of aluminized liners, express mailers, large shipping bags, gel packs and insulated panels for the building industry.

# Portable Cooler/Warmers

**Below** is a selection of Koolatron* portable electronic refrigerators manufactured by Koolatron Division of Urus Industrial Corporation, Brantford, Ontario and Batavia, New York. They are "NASA-inspired" devices, according to company literature, based on the technology of thermoelectric temperature control refined for space applications.

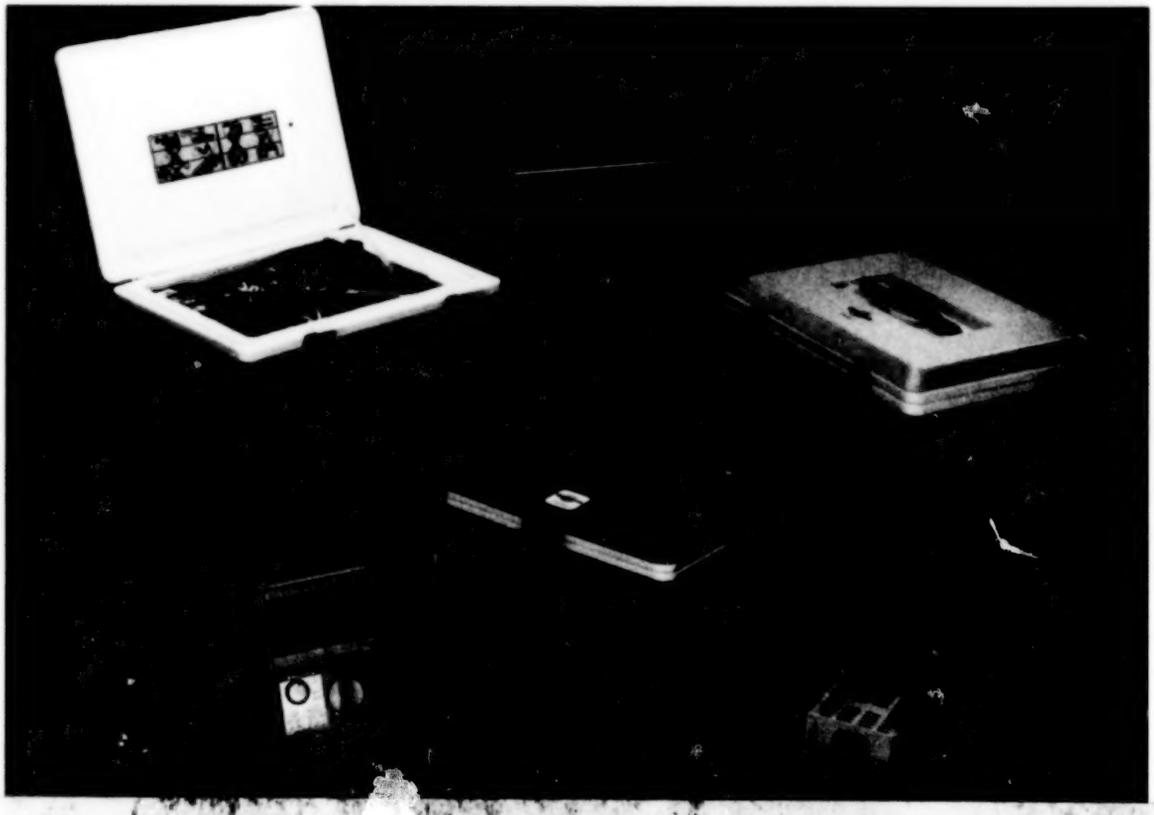
Thermoelectric technology has been around in theory for 170 years and in actual use for decades, for defense and aerospace applications and in certain specialized air conditioning/refrigeration applications, such as submarines and infrared detectors. A thermoelectric cooler module consists of a number of semiconductor couples, connected in series and sandwiched between two ceramic plates. When connected to a DC power source, current causes heat to move from one side of the module to the other. In the cooler, the cold side is exposed to the contents of the cooler, and the hot side to a heat sink that dissipates heat to the environment. If the current is reversed, the heat is moved in the opposite direction and the cooler becomes an effective food warmer.

Early in the U.S. space program, NASA recognized a need for some form of space cooling system that would not require the bulky coils and compressors and motors of conventional refrigerators. This requirement sparked research toward adapting thermoelectric technology to very small, lightweight, compact coolers. NASA's contribution to thermoelectrics was development of miniaturized thermoelectric components and packaging them in small units for use in the tight confines of spacecraft.

The NASA technology is the key to Koolatron's cooler/warmers, each of which employs one or two miniaturized thermoelectric modules. Each module is only about the size of a book of matches, but it delivers the cooling power of a 10-pound block of ice. In the cooling mode, the module reduces the outside temperature by 45 degrees Fahrenheit; in some models, a flick of a switch converts the cooler to a warmer with a capability of 125 degrees. Other than the small fan for blowing the heat away, Koolatron products have no moving parts to wear out or break down.

Koolatron manufactures portable Koolatrons in five models of varying capacity from nine to 48 12-ounce cans; they are plugged into the cigarette lighters of autos, recreational vehicles, boats or motel outlets. The company also offers a built-in model for home use.

* Koolatron is a registered trademark of Urus International Corporation.

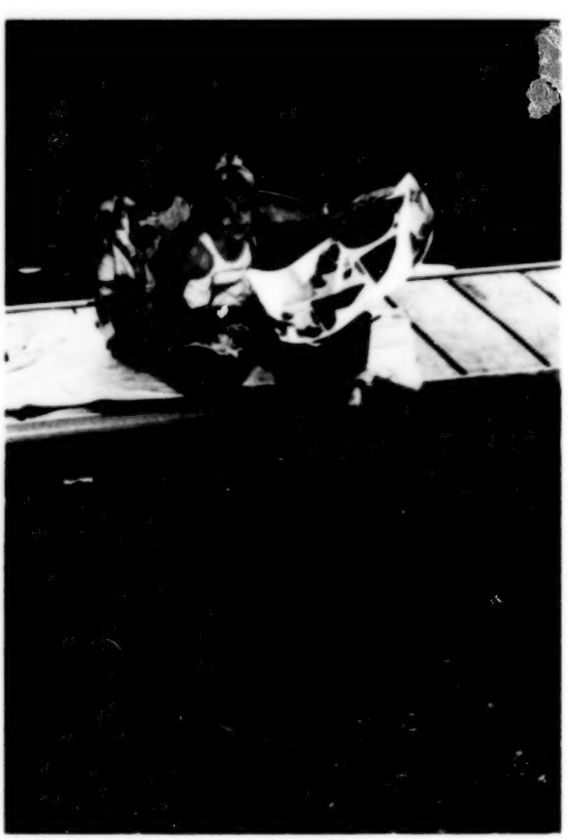


# Water Purification Systems

Consumer/Home/Recreation

**At left** is a view of the dolphin pool at the Clearwater Marine Science Center, Clearwater Beach, Florida; **below** is the center's sea turtle tank. Because high levels of chlorine cause damage to the skins of dolphins and turtles, the Marine Science Center employs a chlorine-free system of water purification. The system, manufactured by Clearwater Pool Technologies, Inc., Largo, Florida, is based on technology developed by NASA during the Apollo Lunar Landing Program.

In the 1960s, Johnson Space Center conducted a research program aimed at development of a small, lightweight water purifier that would require minimal power and no astronaut monitoring; it was intended to supply pure drinking water for three-man Apollo crews on missions up to two weeks. From that research emerged an electrolytic silver ion generator only slightly larger than a cigarette pack and weighing only nine ounces. One or more units, mounted at various locations in the potable water supply on Apollo or later spacecraft, would disperse silver ion concentrations of 100 to 300 parts in a billion, sufficient to eliminate the bacteria in the water within hours.



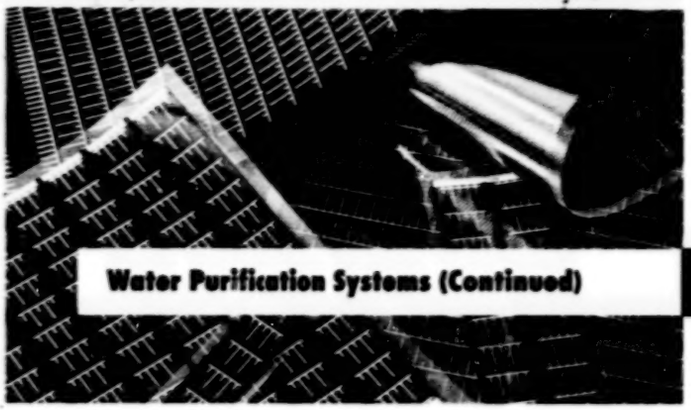
This technology has found broad application because it offers an alternative to use of chemical disinfectants, long the standard method of controlling such water pollutants as bacteria, algae and viruses. In recent years, stricter government rules regarding discharge of chemicals into public water supplies, along with increasing costs of complying with environmental regulations, have expanded interest in non-chemical or minimally-chemical water treatment systems.

A number of companies have acquired NASA licenses to commercialize the NASA technology in water management systems. In many instances, they have used the NASA technology as the core of a system and incorporated advancements or refinements developed through their own research efforts.

Clearwater Pool Technologies employs silver/copper ionization to purify water bodies like the Marine Science Center dolphin/turtle pools. The ClearWater Pool Purifier **(above)** consists of a microcomputer that monitors water conditions; a pair of metallic electrodes; and a rheostat controller. Ions are generated by passing a low voltage current through the electrodes. Distributed throughout the pool, the silver ions kill the bacteria and the copper ions kill algae. The controller automatically introduces the correct amount of ions to the water.

Clearwater Pool Technologies employs variations of the basic technology in a number of other applications. For cooling towers, the ClearWater Purifier cleans tanks of bacteria and algae, while a ClearWater Magnetizer attacks the "scale" and corrosion that commonly build up in such towers. The company produces systems for cleansing spas, hot tubs, water recycling systems, systems for bacteria/algae control in ponds and marine saltwater habitats, systems for hospital water purification, and systems for purifying drinking water in Latin America and the Caribbean.

(Continued)



## Water Purification Systems (Continued)

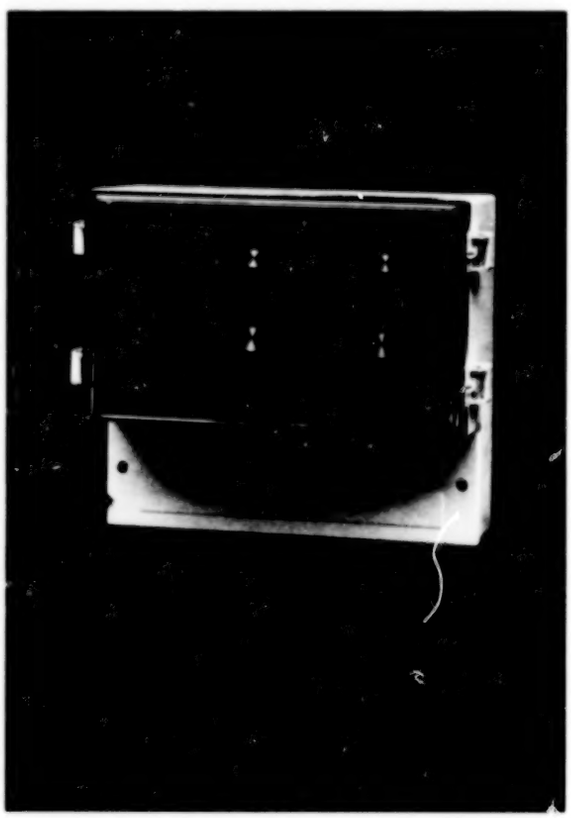
Consumer/Home/Recreation

Among the many users of NASA's silver ionization technology for water purification is Caribbean Clear® USA,Inc., Hilton Head Island, South Carolina. For more than a decade, Caribbean Clear has been using the silver ion approach as the core technology of its water treatment systems, but the company's own R&D work continues to generate advancements of the basic technology.

An example is the AquaKing shown **at left below**, a system designed for market areas where there is no municipal or satisfactory source of acceptable drinking water. The unit shown is the company's Model AK-20, which automatically provides 20,000 liters of pure, bacteria-free drinking water daily.

The AquaKing combines four technologies. First, it uses a physical catalyst to condition the water and eliminate scale buildup. Next, it uses advanced filtration technology to filter out unwanted color, odor, taste, sediment, chlorine and other contaminants. Then it uses the NASA-developed technology to purify the water by means of silver/copper ionization. Finally, it employs a submicron filter array that removes microscopic particles and organisms.

Another company advancement is the Caribbean Clear Controller, which automatically controls pH, chlorine and ionization levels. The Controller system **(below right)** is designed for commercial pool and water park



applications where sanitizing is combined with feedback control of pH and an oxidizer, chlorine or bromine.

The key to the system's effectiveness, according to company sales literature, is "proportional control." Where some controllers simply offer "on/off" control, the Caribbean Clear Controller automatically adjusts the rate at which chemicals are fed into the water, based on a precise measurement of the rate at which the chemicals are being consumed. Proportional control prevents overfeeding, or slow response when there is a sudden change in chemical demand. The Controller, the company says, offers chemical savings up to 80 percent through a combination of proportional control and computer-controlled ionization.

The mainstay of Caribbean Clear's business is still the pool purification system based on the original NASA technology, although it has undergone a number of advancements and refinements. The company produces a family of models ranging from in-home spa size to multi-million gallon facilities. Caribbean Clear also offers customized systems for specific applications, such as salt water rookeries or koi ponds; such systems present special challenges, either because of non-standard water chemistry (as in a sea lion rookery) or because of the low tolerance to copper exhibited in some species of fish.

* Caribbean Clear is a registered trademark of Caribbean Clear USA, Inc.

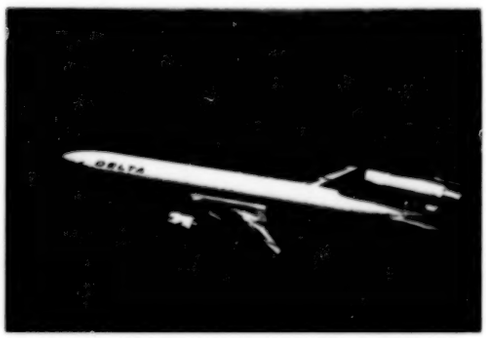
# Winglets for the Airlines

Performance-improving airfoils for jetliners head technology transfers in the field of transportation

One important way in which government technology is transferred to the civil economy is NASA's aeronautical research program. The agency seeks to develop advanced technology for coming generations of aircraft and at the same time provide new technology to resolve aviation's most pressing current problems. This effort exemplifies the direct benefit transfer, involving development of technology to meet a specific need, as opposed to the indirect benefit that accrues from spin-off, the secondary application of technology developed originally for the needs of NASA's mainline programs.

For more than three quarters of a century, NASA and its predecessor agency have contributed a truly impressive array of innovations over a very broad spectrum of aviation needs. This work has significantly benefited the U.S. economy by elevating the competitive posture of America's plane builders in the international market place; it has benefited those who fly by contributing to flight safety and airplane performance; and it has benefited the general public by improving the environmental characteristics of flight systems.

An example of NASA's aeronautical research is the winglet, a sort of upturned wingtip that is seen more and more frequently at airports. Originally developed by Langley Research Center, the winglet has been in service for more than 15 years aboard business jets and other aircraft, and now it is in regular airline service as a fuel-saving aid to such long-ranging aircraft as the MD-11 jetliner, built by McDonnell Douglas Corporation's Douglas Aircraft Company, Long Beach, California.




*Winglets are in airline passenger service on the McDonnell Douglas MD-11 trijet, pictured here in Delta Air Lines livery.*

A vertical extension of the aircraft wing, the winglet is a lifting surface designed to operate in the wingtip "vortex," a whirlpool of air that occurs at an airplane's wingtips. The vortex is a complex, turbulent flow that creates drag; the winglet's job is to take advantage of the turbulent vortex flow by producing a degree of forward thrust, in a manner much like a boat's sail. This extra thrust reduces drag and provides a substantial improvement in fuel efficiency, which can be translated into greater payload or longer range for a given fuel load.

Langley's winglet work was part of the Aircraft Energy Efficiency program, NASA's contribution to the national energy conservation effort during the oil crisis years of the 1970s. Langley successfully demonstrated the basic winglet technology in wind tunnel and flight tests, but since the wingtip vortex effect differs with each aircraft, final design and validation remained a question for aircraft manufacturers. To promote the widest possible use of winglets, NASA awarded contracts to aircraft manufacturers for studies of what the winglet


*Shown undergoing test aboard a NASA research aircraft, winglets (the vertical extensions of the wingtips) act like boat sails to produce extra thrust and lengthen an airplane's range.*

could do for certain existing commercial aircraft and for airplane designs still on the drawing board.

Douglas Aircraft conducted three such studies for NASA in 1978-79, one of them involving wind tunnel tests of winglets on the company's DC-10 transport, another on the application of a complete wing/winglet system to a hypothetical advanced commercial airliner. Both studies showed that significant performance gains, in particular reduced fuel consumption, could be realized by use of winglets.

NASA and Douglas teamed on a 1982 flight test program of a DC-10 trijet fitted with winglets and once again found that the airfoils offered a measurable improvement in fuel consumption. That was an important consideration for Douglas Aircraft at that time, because on the company's drawing board was a larger, high capacity, advanced technology derivative of the DC-10; ultimately to become the MD-11, the big trijet was intended for the extra-long routes across the Pacific Ocean and it was to be one of the longest-ranging planes ever flown.

The MD-11 development program began in 1986. From the beginning, its designers incorporated winglets as an important part of the configuration to help attain the required combination of large payload (290-plus passengers) and very long range (more than 8,200 miles). The MD-11 made its first flight in January 1990 and the 10-month certification flight test program that followed verified the expected aerodynamic benefits of the winglets. The trijet transport went into airline service early in 1991 and there are now more than 100 MD-11s plying the world's airways.

# Lightning Protection

Transportation

The Glasair III is a homebuilt aircraft produced from a kit manufactured by Stoddard-Hamilton Aircraft Company, Arlington, Washington. Kit-built airplanes are more affordable, in part because they are assembled by the owner and in part because they do not require Federal Aviation Administration (FAA) testing and certification, which can be costly.

FAA treats homebuilts in different fashion from factory produced general aviation planes. They are considered to be experimental, thus cannot be used for commercial purposes, and the owner/operator is considered to be the manufacturer and therefore responsible for safety — so the rigorous safety testing and certification process normally required for general aviation aircraft is waived.

The Glasair III is an advanced technology homebuilt, constructed of a fiberglass and graphite fiber composite material and equipped with digital instruments. Composites offer greater airframe strength at reduced weight; digital systems provide greater efficiency in cockpit displays. However, both technologies tend to make the airplane more susceptible to lightning effects than conventional instruments and metal airframes because composites are less conductive than the aluminum alloys they replace, and because lightning strikes may interfere with sensitive digital electronics.

Since the Glasair III is capable of cross-country flight, Stoddard-Hamilton felt that its customers wanted the ability to use the airplane in instrument flight conditions. Because instrument weather conditions are very often the same conditions that produce lightning, the company decided that a lightning-protected version of the Glasair III would also enable more extensive instrument flight, enhancing safety and improving the marketability of Glasair III.

Because NASA conducts a continuing program of research toward improving general aviation safety and performance, Stoddard-Hamilton proposed to Langley Research Center a joint development program to develop and test a Glasair III-LP (Lightning Protected) version that would be able to land safely if struck by lightning. Langley, which had long conducted a multiyear Storm Hazards Research Program, was interested because the airplane was made of composites and there was need for a database on this type of general aviation aircraft.

Accordingly, Langley awarded a Small Business Innovation Research contract to Stoddard-Hamilton for the development. Lightning Technologies, Inc. (LTI), Pittsfield, Massachusetts, one of the key players in the Storm Hazards Research Program, was selected as the subcontractor responsible for the lightning protection design and testing. Analytical Services and Materials, Hampton, Virginia and Aero Space Consultants, Newport News, Virginia provided engineering and documentation support.

**The accompanying photos** illustrate a key test in the Langley/industry Glasair program. The prototype Glasair III-LP is being subjected to a 1.5 million volt strike-attachment test in LTI's simulated lightning laboratory, one of a battery of tests normally required by the

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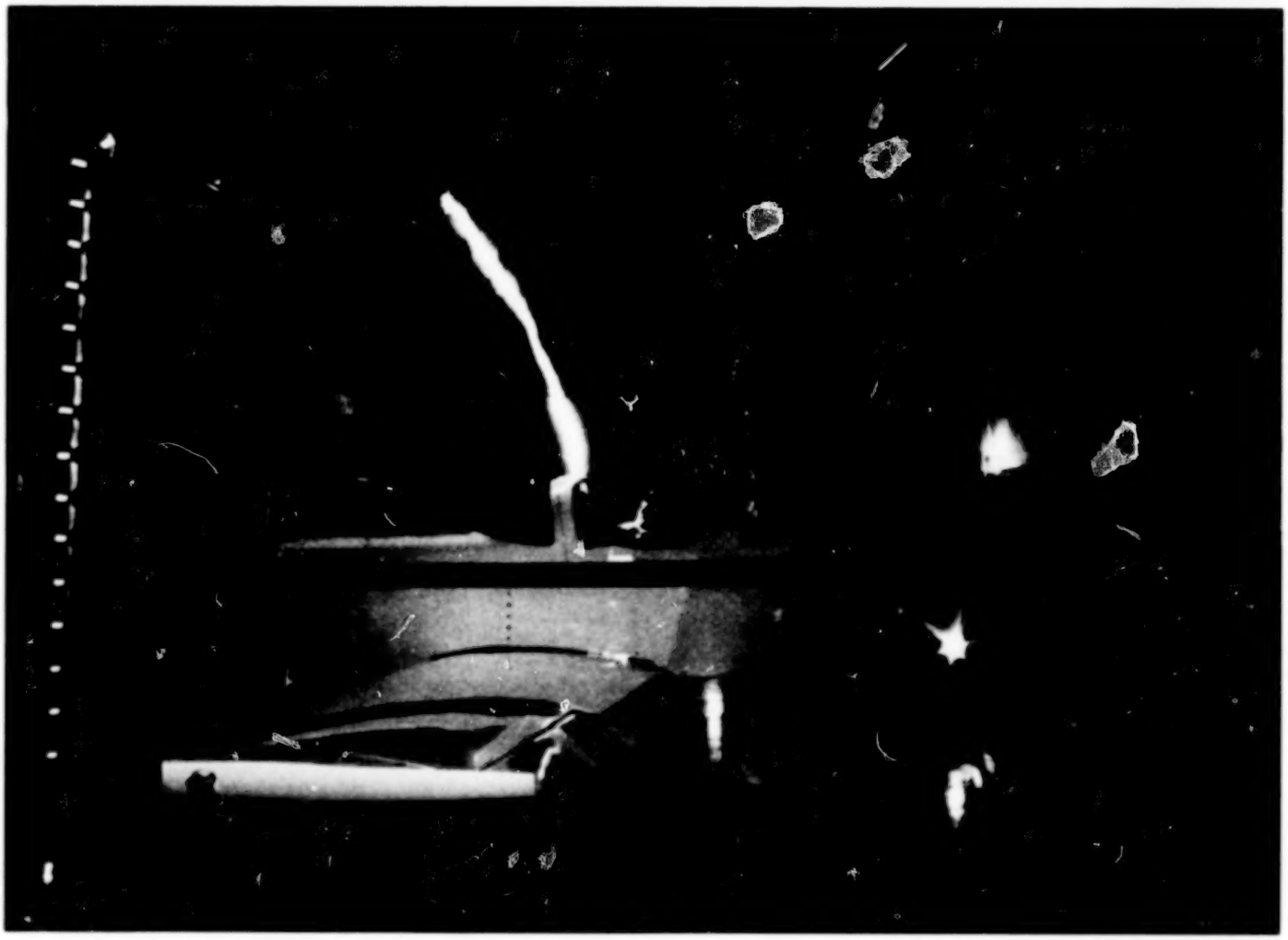


FAA for certification of a factory-produced aircraft. The Glasair III-LP successfully passed this and other tests and became the first kit-built composite aircraft to be lightning tested and protection-verified under the guidelines used by the FAA to certify general aviation aircraft.

To achieve that status, LTI designed a protection system to ensure that lightning would not cause catastrophic structural damage, disabling electrical shocks to occupants, loss of aircraft control, ignition of fuel vapors, loss of propulsion, loss of instrument flight rules (IFR) capability, or loss of electrical power or engine controls.

Because the Glasair III is constructed of fiberglass composites that offer no inherent protection against lightning, a layer of expanded aluminum foil was added to the surface of the fiberglass to provide basic electrical continuity and shielding for the entire airframe. Special attention was given to the electrical bonding of aircraft components to allow safe passage of lightning currents on the exterior of the aircraft.

The fuel system was protected by a specially designed fuel filler cap and by the isolation of fuel and fuel gauges from conducting surfaces. The interior compartment was entirely isolated from the exterior conducting surfaces and an equipotential plane was provided to minimize voltage difference throughout the airplane. The electrical and avionics systems were protected by careful attention to grounding and shielding and by the use of surge suppression devices.

# A Motionless Camera

Highlighting spinoff examples in the field of computer technology is a novel electronic imaging system

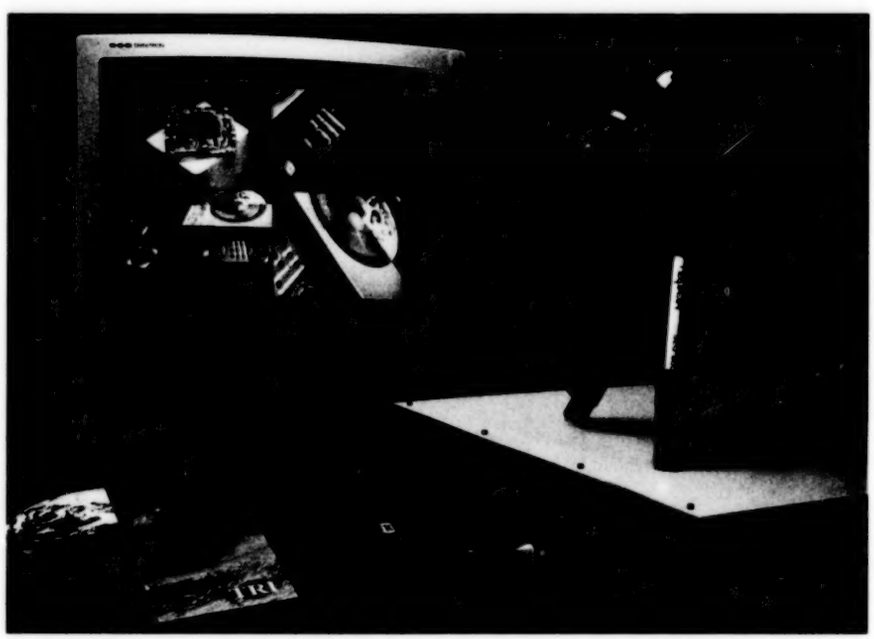
*Omniview*™ is a camera system, a very different camera system. It can see in more than one direction and provide as many as four views simultaneously, each with its own pan, tilt, rotation and magnification. And for all that it has no moving parts.

Developed by TeleRobotics International, Inc. (TRI), Knoxville, Tennessee under a NASA Small Business Innovation Research contract, *Omniview* was introduced to the commercial market in 1993 and in the same year it won an R&D 100 Award, presented by *R&D Magazine* as one of the most technologically significant products of the year.

The camera was intended primarily for NASA use as a viewer for space teleoperation of robotic systems, where size, weight and power consumption are at a premium, and reliability and fast response are among the most important factors. Therefore, *Omniview* was developed to eliminate the pointing mechanisms and mechanical links normally required for rotating, panning and tilting the camera; all these functions are handled electronically. The result is a motionless, noiseless, exceptionally versatile camera whose capabilities can be advantageously employed in a broad variety of applications.

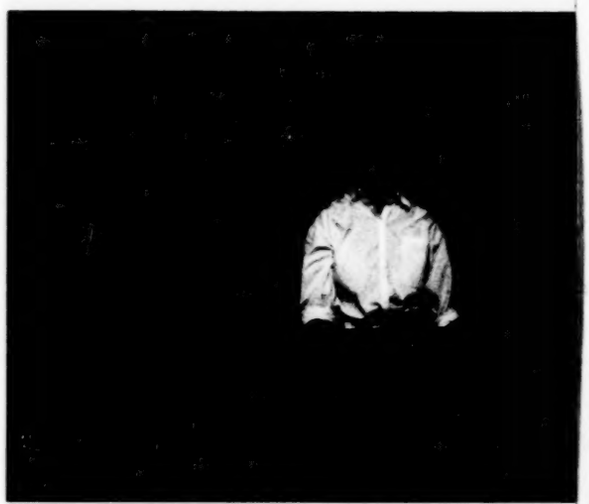
*Omniview's* image transformation electronics produce a real-time image from anywhere within a hemispherical field, such as the circular image provided by a fisheye lens with a 180 degree field of view. A video image viewed through a fisheye lens would be distorted, but *Omniview* automatically removes any lens distortion from the image and presents a corrected "flat" view on a monitor.

Among the key elements of the system are a high resolution CCD (charge coupled device); image correction circuitry governed by two TeleRobotics devel-



***Originally developed as a viewing device for guiding space robots, the* Omniview *camera (on tripod) can photograph up to four objects simultaneously without moving its lens; the rotating, panning and tilting functions are handled electronically.***

*Surveillance of an apartment building lobby is one of many* ***Omniview*** *applications. A video image viewed through a wide angle fisheye lens would be badly distorted as shown at left, but* ***Omniview*** *removes the distortion and presents a corrected "flat" view on the monitor; note the distortion of the staircase in the fisheye view and the corrected closeup below.*



oped mathematical equations; and a microcomputer for image processing. Because the digital transformation process will work with almost any type of camera, *Omniview* can be adapted to existing installations where cameras are already in place — for example, a building installation designed to allow a security officer to observe various parts of the building on a console. Four different cameras can be run through the same processor. Company literature describes the versatility of the system:

"With high resolution imaging devices, the *Omniview* system can provide a complete viewing solution that simultaneously replaces the functionality of multiple cameras, their pointing mechanisms, and their associated cabling and electronics. With infrared sensors, *Omniview* can also be used for night vision."

The system can be used in such applications as security and surveillance, teleconferencing, medical and industrial imaging, virtual reality, broadcast video, and in military operations such as observation missions by unmanned aerial vehicles.

™ Omniview is a trademark of TeleRobotics International, Inc.

# Calculation Software

Computer Technology

MathSoft, Inc., Cambridge, Massachusetts is a leading developer of calculation software for desktop computers. Founded in 1984, MathSoft released its principal product —Mathcad® — a year later. Mathcad provides an easy-to-use software alternative to scratchpads, whiteboards, calculators and spreadsheets.

A new version of the software package, Mathcad Plus 5.0, was introduced to the market in January 1994. Designed for such users as electrical engineers and computer scientists who need advanced math functionality, Mathcad Plus 5.0 incorporates an expert system that determines a strategy for solving difficult mathematical problems, then provides the solution. This new capability — called SmartMath™ — extends the interactive nature of Mathcad, which automatically updates results as variables or formulas change.

SmartMath resulted from a company effort involving integration into Mathcad of CLIPS (C Language Integrated Production System), a NASA-developed shell for creating expert systems. CLIPS is designed to allow for the research, development and delivery of artificial intelligence in conventional computers. A collection of conditions, and the actions to be taken if such conditions are met, are constructed into a rule network by the CLIPS "rule engine." As facts are asserted, they are matched to the rule network. The versatility and portability of CLIPS has made it a valuable research tool for a variety of applications.

Described as a major advance in calculation software, SmartMath provides an intelligent interface between the user's problem and Mathcad's numeric and symbolic capabilities. By using the NASA-developed program, MathSoft saved the time and money involved in writing a program from scratch.

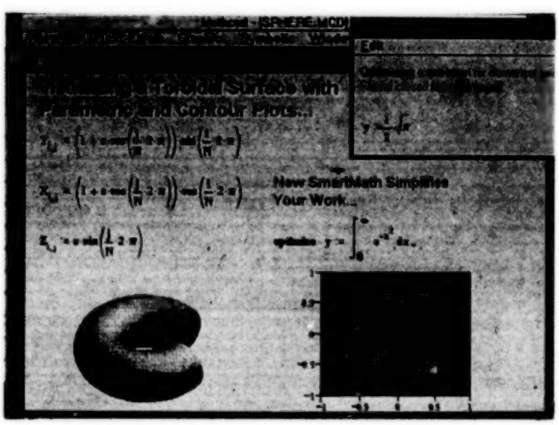
SmartMath reviews the user's input and executes a strategy for solving the problem by writing a new set of Mathcad Plus equations in a pop-up window and delivering the results to the Mathcad Plus document. The user is thus freed from having to construct his own Mathcad solutions. Mathcad Plus 5.0 enables users to interact with every number and symbol in a wide range of graphs and plots **(photos)**.

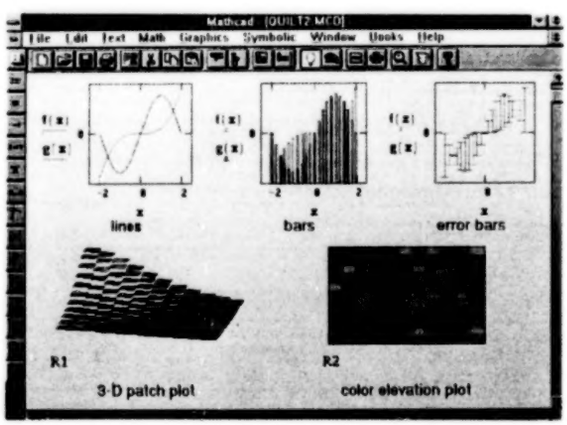
CLIPS was made available to MathSoft by NASA's Computer Software Management and Information Center (COSMIC)®. Located at the University of Georgia, COSMIC supplies industrial and other organizations government-developed computer programs that have secondary applicability (see page 128).

® Mathcad is a registered trademark of MathSoft, Inc.

™ SmartMath is a trademark of MathSoft, Inc.

® COSMIC is a registered trademark of the National Aeronautics and Space Administration.



# Data Acquisition Systems

In the mid-1980s, Kinetic Systems Corporation, Lockport, Illinois teamed with Langley Research Center on a joint study and development program. The study invoived feasibility determination of using high speed CAMAC (Computer Automated Measurement and Control) data acquisition systems in Langley's Advanced Real Time Simulation (ARTS) system, which supports flight simulation R&D in such areas as automated control, navigation and guidance, air combat, and workload analysis for pilots and astronauts.

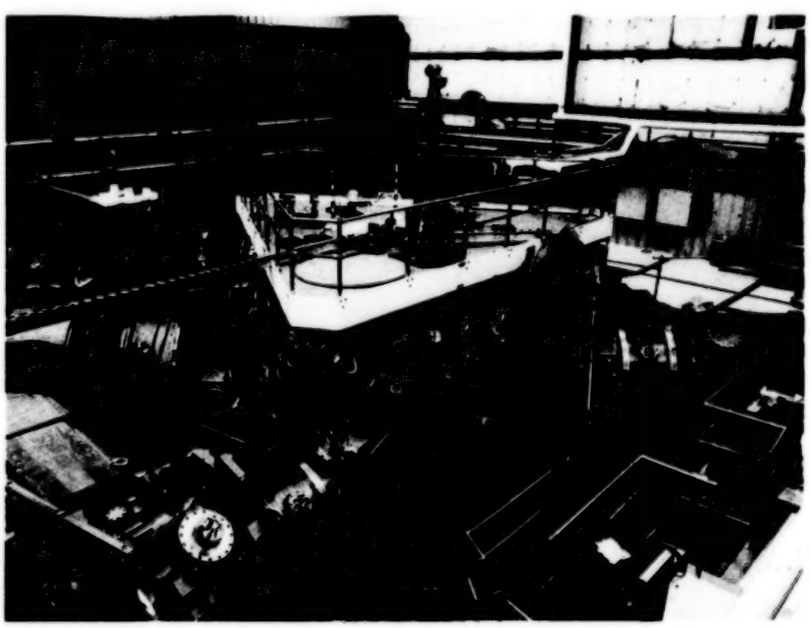
The study found that CAMAC equipment could significantly improve the ARTS system by allowing 32 high performance simulators located throughout the Langley complex to be controlled by centrally-located host computers. With Langley input, Kinetic Systems proceeded to develop the requisite hardware, such as an advanced performance fiber optic data highway and a series of digital to analog, analog to digital, and digital to synchro converter modules. The technology developed for ARTS broadened Kinetic Systems' technical capabilities and brought a number of commercial applications.

An example is the fusion research program conducted by General Atomics (GA), San Diego, California, the goal of which is to develop a commercial nuclear fusion reactor that can be operated safely and economically.

At the heart of this research is the DIII-D experimental tokamak **(below)**, designed and built by GA and operated by the company under contract to the Department of Energy. The tokamak is used to explore improvements in reactor grade fusion plasmas by magnetic shaping. A "shot" (a test plasma burst) lasts only five to 10 seconds but generates about 100 megabytes of data.

To handle an increasing flow of data, GA recently upgraded its computer system and in the process added an enhanced serial highway and associated components originally developed by Kinetic Systems for Langley's ARTS. The combination of GA's new computer system and the Kinetic Systems equipment allows GA to acquire tokamak data from four to 15 times more rapidly.

Another project that uses the technology developed for NASA is Ford Motor Company's transmission test cell program in Livonia, Michigan, where Ford tests auto transmissions for durability, performance and efficiency. Ford operates 24 test cells **(above)** that use sophisticated computer programs to control and monitor the tests; each cell also contains a Kinetic Systems CAMAC-based data acquisition and control system. That the relatively new test cells are performing successfully is evident in the fact that Ford is installing an additional 24 cells at Livonia. For marketing its equipment to these and other customers, Kinetic Systems is engaged in cooperative marketing partnerships with Digital Equipment Corporation, Marlborough, Massachusetts and Hewlett-Packard Company, Cupertino, California.



# Analytical Instrument

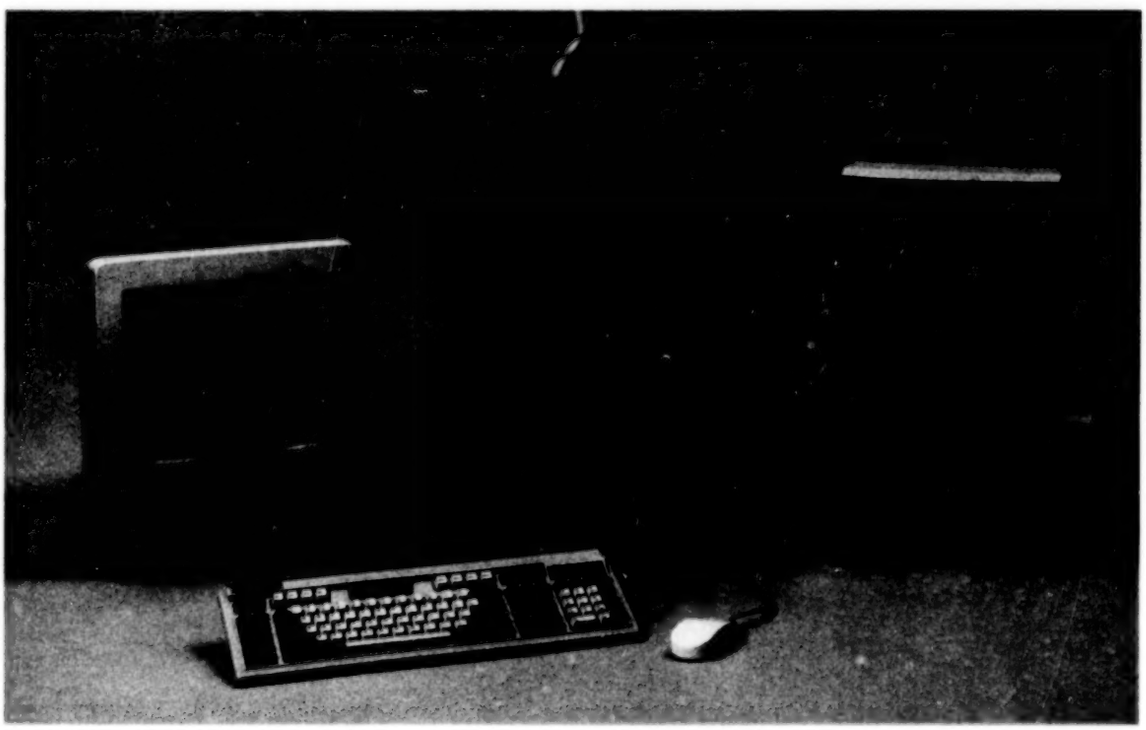
Computer Technology

**At right**, a researcher is inserting a sample into a BEEM (Ballistic Electron Emission Microscopy) system, described as a system that allows scientists to peer into the electronic structures of semiconductor devices. **below** are the components of the BEEM system, which was developed at Jet Propulsion Laboratory (JPL), engineered by Atomis, Inc., Berkeley, California and introduced to the commercial marketplace by Surface/Interface Inc., Mountain View, California.

BEEM is a research instrument invented by a trio of scientists at JPL's Center for Microelectronics Technology: Douglas Bell, Michael H. Hecht and William J. Kaiser. The invention won for the trio an R&D 100 Award in 1990 because of the significance of the technology to microelectronic research. Analytical instruments that produce images of surface structures are in wide use, but BEEM goes a step further with the ability to image underlying layers or interfaces.

BEEM was conceived as a tool for advanced research on semiconductor devices. Co-inventor Michael Hecht says that "almost everything of interest in semiconductor devices happens at interfaces, not on surfaces." BEEM injects a tiny current into a metal layer and the electrons travel ballistically through the metal; this allows the researcher to look at the interface and surface simultaneously to study the operation and performance of a structure.

Among BEEM advantages cited by JPL are the option to inject either electrons or holes to nondestructively image barrier heights and characterize devices electronically; the ability to image interface and surface using an instrument that operates in air, liquid or in a vacuum; and the potential to observe processes such as molecular beam epitaxy (crystal growth) in situ.



# Disk Drives

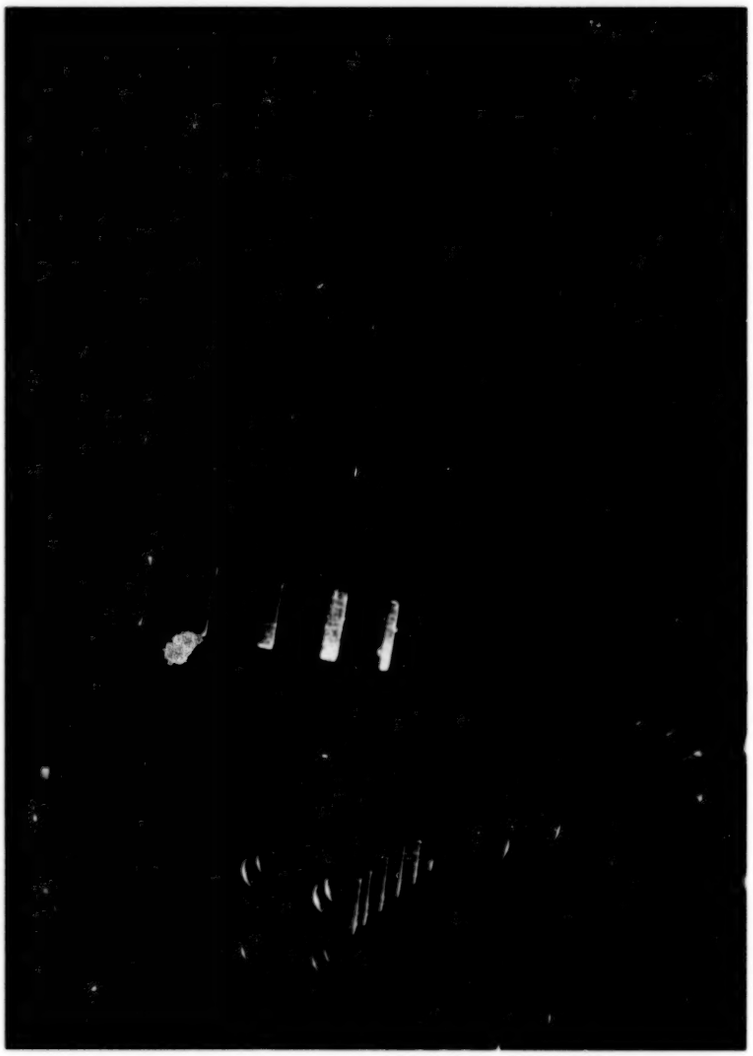
**Shown below** are computer disk drives containing components made of a new material known as AlBeMet™, which is a compression of "aluminum beryllium metal matrix composite." The material was developed by Brush Wellman, Inc., Cleveland, Ohio for research applications in the National Aero-Space Plane (NASP) program earlier conducted jointly by NASA and the Department of Defense, no longer active.

The NASP program was structured to develop the enabling technologies for future hypersonic and transatmospheric vehicles that offer low cost access to space. Because such vehicles would be capable of operating within the atmosphere for long periods, they would encounter temperature extremes well beyond those the Space Shuttle experiences, hence materials development has been a particular focus of NASP. To enable the vehicles to withstand such temperatures, NASP researchers investigated a number of lightweight, high strength, oxidation-resistant materials for both airframe and engine structures, including metal matrix, organic, refractory and highly conductive composites.

AlBeMet is one such advanced material. It combines the low density and high stiffness of beryllium with the ductility, ease of manufacture and low cost of aluminum. The material reduces system weight and its high thermal conductivity can effectively remove heat and increase an electrical system's lifetime. First applied to spacecraft structures and to the electrical subsystem of an advanced technology military aircraft, AlBeMet has moved into the commercial market. Brush Wellman Applications Development Center is producing an AlBeMet rotary actuator for high performance disk drives manufactured by Maxtor Corporation, San Jose, California.

The AlBeMet 160 used in the disk drive is as stiff as steel and lighter than aluminum, and it has 3.5 times the stiffness/weight ratio as aluminum alone. A lighter, stiffer arm assembly means the heads can be moved faster, improving disk performance. According to Brush Wellman, the material allows the disk drive to have a mean access speed 20 percent faster than would be possible with any other material on the market. Because of the material's stiffness, fingers were able to be reduced by one-third the thickness, allowing twice as many disks in the same space.

™ AlBeMet is a trademark of Brush Wellman, Inc.



# Software Management System

Computer Technology

In the early 1980s, Goddard Space Flight Center (GSFC) sponsored development of a software management system to support image processing and remote sensing applications. Known as the Transportable Applications Environment (TAE)*, it was developed for GSFC by Century Computing, Inc., Laurel, Maryland.

TAE was designed to help system developers and end users in organizing and managing the multiple programs often involved in computer solutions to information management problems. It provides user interface development tools and a stable framework in which a system can be built, and it lowers the cost of system development and software conversion by providing software and structures for commonly recurring requirements.

Over the years, TAE evolved from a traditional menu and command oriented system to a state-of-the-art user interface development system supporting high resolution graphic workstations. Through NASA's Software Management and Information Center (see page 128), GSFC distributed the software to more than 900 government, academic and private sector users, periodically upgraded the system, and backed it with a TAE Support Office that assisted users on specific problems.

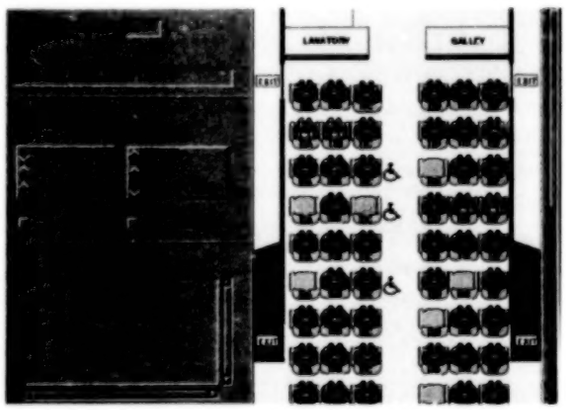
In 1993, however, GSFC decided to complete the technology transfer process for TAE and asked Century Computing to take over support and commercial distribution of the software. Through a Century/GSFC agreement, the company was awarded lifetime rights to market TAE Plus, the latest version of the software system, and Century will make the software available to NASA at no cost for five years. Century also assumed responsibility for upgrades and support services associated with TAE Plus.

Century Computing introduced TAE Plus to the commercial market in October 1993 as a tool for building graphical user interfaces. The TAE Workbench lets a user lay out an interface interactively, choosing from a set of building blocks called "presentation types." The user selects the presentation types he wants, uses a mouse to position and resize them on a display, and sees the interface just as the end user will see it. Writing code is not necessary; the TAE Plus Code Generator writes the interface code, which can then be easily integrated with the application code.

| | A | B | C | | D | E | F | |
|---|---|---|---|---|---|---|---|---|
| 9X | | /B | .B | ** | /B | /B | | X |
| 10X | / | / | / | ** | . | / | . | X |
| 11M | . | . | .H | ** | . | . | . | |
| 12M | . | / | .H | ** | / | . | . | |
| 13M | . | / | . | ** | / | . | . | |
| 14M | . | . | . | ** | / | E | . | |
| 15M | . | . | .H | ** | . | . | . | W |
| 16M | . | . | . | ** | / | E | . | W |
| 17X | / | / | / | ** | / | / | / | XW |
| 18X | . | / | . | ** | / | / | / | XW |
| 19W | . | . | .H | ** | . | E | . | W |
| 20W | . | . | . | ** | . | E | . | W |
| AVAIL: | SEAT | LETTER | LEAST PREF | :U | SMOKING | :- | BULKHEAD | :B |
| TAKEN: | . | | UPPER DECK | :J | NOSMOKE | :** | WING | :W |
| BLOCK: | / | | HANDICAP | :H | BUFFER | :/ | EXIT | :X |

The accompanying illustrations show a comparison between a type of display used by many travel agents to select airline passenger seating **(above)** and a TAE Plus version of the seating chart, created without programming **(below)**. Century Computing literature stresses that use of the TAE Plus requires little computer experience: "If you can use a mouse, you can build an effective graphical user interface with TAE Plus."

* TAE is a registered trademark of Century Computing, Inc.



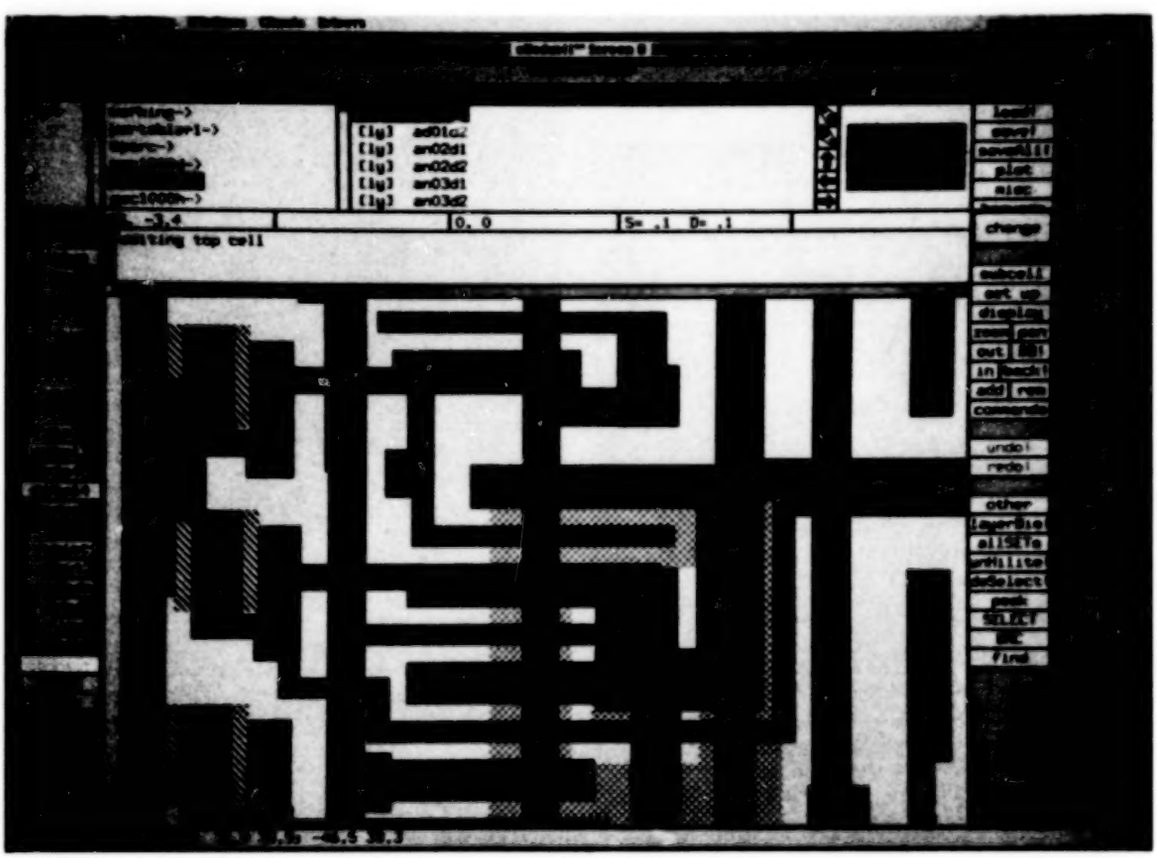
# Cell Libraries

Silicon has historically been the material of choice for digital integrated circuits but there are faster and more energy efficient semiconductor materials on the horizon. One in which NASA is investing considerable research effort is gallium arsenide (GaAs). Electrons are conducted 4-6 times faster through GaAs than through silicon, which offers processor performance of 500 megahertz and above. This, coupled with advantages of lower power consumption at frequencies above 100-150 megahertz, makes GaAs a very attractive replacement for the silicon-based CMOS (Complementary Metal Oxide Semiconductor).

Though promising, GaAs has been slow to catch on. As a material, it is expensive, inherently brittle and easily damaged in fabrication and packaging. Perhaps the greatest drawback to its use as a mainstream semiconductor material has been the lack of computer automated engineering tools for designing GaAs integrated circuits as efficiently as CMOS chips.

What is described as a "breakthrough solution" to the gallium arsenide design automation problem has been provided by Systems & Processes Engineering Corporation, Austin, Texas. Under funding from Goddard Space Flight Center, (GSFC), SPEC has developed a series of GaAs cell libraries that work as an extension to the integrated circuit design tools produced by COMPASS Design Automation, San Jose, California. The cell libraries are used for such operations as cell layout, design rule checking, logic synthesis, placement and routing, simulation and chip assembly. **Below** is an on-screen view of the physical layout of a gallium arsenide standard cell in the design process, as generated by the COMPASS tools using the SPEC GaAs libraries.

COMPASS, one of the leading producers of electronic design automation software, is marketing SPEC's GaAs cell libraries worldwide. The libraries are a byproduct of SPEC's contract with GSFC for design and development of a 500 megahertz GaAs version of Sun Microsystems' SPARC processor, intended for space applications and for terrestrial computer and communications systems. Developed by means of COMPASS tools and the SPEC libraries, the microprocessor is targeted to Vitesse Semiconductors H-GaAs III process technology.



# Image Compression Devices

Computer Technology

**Below**, engineer Bill Thompson of Advanced Hardware Architectures (AHA), Pullman, Washington is conducting a reliability test on an integrated circuit tester. The product he is testing is a new, two-chip Image Compression Chip Set **(bottom right)** developed by the NASA Microelectronics Research Center(MRC) and marketed by AHA.

AHA is a spinoff company, started by former employees of the MRC when the center was located at the University of Idaho; MRC is now the NASA Space Engineering Research Center for VLSI (Very Large Scale Integration) Systems and it is located at the University of New Mexico. In February 1988, a number of MRC researchers established AHA as a semiconductor company focused on the emerging market for advanced data coprocessor products.

The image compression device pictured is the AHA3370/3371 chip set for medical/scientific imaging applications, such as x-ray and ultrasound imaging. Other members of the AHA Series 3000 family are designed for applications in storage devices and general purpose printers.

The AHA3370/3371 set is based on Rice algorithm technology originally developed at Jet Propulsion Laboratory by Robert F. Rice and implemented in VLSI by MRC. The Rice algorithm is a "lossless" compression algorithm; it takes an image or other data that has been broken down into short strings of digital data and processes each string mathematically to reduce the amount of memory it takes to store them, or the time it takes to transmit them. In lossless compression, the data is completely restored after decompression. Other algorithms, called "lossy" algorithms, compress by throwing away insignificant portions of the data, a technique appropriate for some applications but not for medical, scientific or engineering applications where all data must be preserved.

The Rice algorithm processes the data through 12 different optimal code options and selects the one that gives the best compression for the data on which it is working; this maintains efficient performance as data characteristics vary. With the AHA3370/3371 chip set, the typical compression ratio is 2.5 to 1 and ratios of 7 to 1 or more are possible.

# Hand-held Keyboard

Gary Friedman, an engineer at Jet Propulsion Laboratory, saw a need for a way of keying a computer while on the move, for example, taking notes while walking or driving. So he invented a single-handed data entry device dubbed the Data Egg **(right)** that can be used by an astronaut in space, a journalist at a press conference, by a bedridden person, or by anyone for "idea capturing" while on the go. The device was developed under NASA contract and it is being marketed by InHand Development Group, Sacramento, California.

The Data Egg is a chord key-based unit that can be used autonomously or tethered to a personal computer as an auxiliary keyboard for those who cannot work at a desk, such as bedridden people. The device resembles a beeper and is worn on a belt when not in use.

Data is entered by pressing combinations of seven buttons positioned where the fingers naturally fall when clasping the Data Egg. Invented in England for pocket electronic devices, the seven-button alphabet can be learned in as little as an hour, according to Friedman. An experienced user can enter text at a rate of 30 to 35 words a minute. The advantage over a tape recorder is that Data Egg text requires no transcription; the input can be downloaded into a computer and printed.

Friedman sees special utility for the Data Egg in extending computer access to bedridden persons and he has developed a prototype Bedridden Workstation. The workstation is formed by tethering the Data Egg to a personal computer and incorporating an innovative display called the Private Eye. In lieu of a CRT screen, the Private Eye places in front of the user's eyes a small box that projects an image of the personal computer's screen five feet in front of the user. The user, lying down, types in text with the Data Egg hand at his side; a program in the personal computer translates the function codes generated by the Data Egg and activates the appropriate characters on the computer's keyboard.

# Plasma Heating: An Advanced Technology

Systems that provide extremely high temperatures for industrial processing exemplify spinoff aids to industrial productivity and manufacturing technology

In 1958 NASA embarked on a program to put man in space, a task of myriad challenges for the technology of that day. Among the many formidable problems to be overcome was the matter of protecting astronauts from the high friction temperatures they would encounter as their spacecraft reentered the atmosphere at very high velocities. NASA's solution was the ablative heat shield, composed of a material that was designed to burn off as the spacecraft plunged into the atmosphere; the burning dissipated much of the heat energy, with the result that the astronauts' cabin usually got no hotter than 80 degrees Fahrenheit even though friction temperatures ran well over 2000 degrees for the Mercury and Gemini Earth-orbiting capsules and as much as 5000 degrees when the Apollo Command Module hurtled Earthward after a lunar mission.

In developing the initial Mercury heat shield, and refining the design for the greater demands of the Apollo spacecraft, NASA faced a problem. The heat shield materials had to be tested and verified on Earth before committing the spacecraft to flight test. But how do you generate temperatures of 5000 degrees or more? That was the big question for the members of a NASA team assembled at Ames Research Center and charged with the important task of developing a Re-entry Heating Simulator to prove the effectiveness of heat shield materials. The answer, discovered only after exhaustive testing of many different heat sources, was plasma heating, which involves passing a strong electric current through a rarefied gas to create a plasma — ionized gas — that produces an intensely hot flame. This technique allows generation of temperatures far greater than those that can be generated by conventional oxygen combustion heaters, temperatures as high as 20,000 degrees Fahrenheit.

With the help of industry firms, NASA designed modern plasma arc heaters and exposed heat shield materials in the laboratory to temperatures well above those they would encounter during an actual reentry. Plasma heating technology made the Ames Re-entry Heating Simulator a reality and, in a sense, made possible American manned space flight.

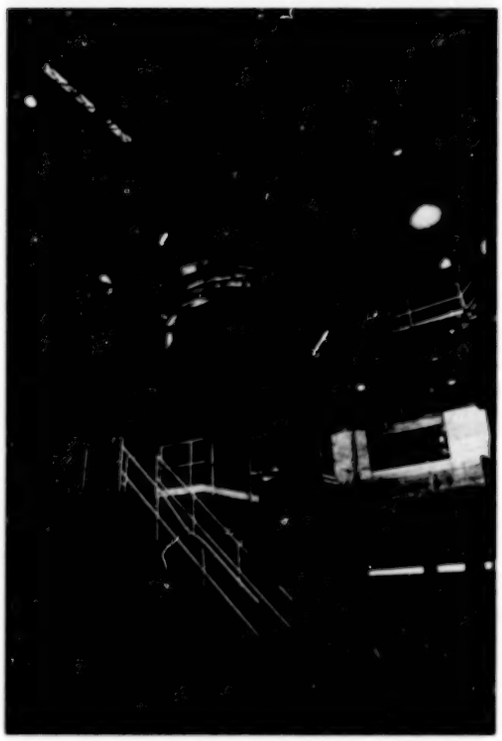
Plasma heating, however, was not a NASA invention. The concept had been around since 1878, although it never found wide usage, and it was still in limited use in European industrial activities when Ames was developing the simulator. But NASA's research spurred a revival of interest in the decades-old technology and influenced a dramatic post-Apollo growth in use of advanced plasma torch systems for industrial processing. NASA's work thus stimulated a stagnant technology and expanded the market for plasma heating systems; some of the NASA technology found its way into the new types of plasma arc torches developed in the 1970s and 1980s.

An example is Plasma Technology Corporation (PTC), Raleigh, North Carolina, a company whose whole product line is based on the NASA technology. PTC scientist Salvador L. "Bud" Camacho was a member of the Ames Research Center team that developed the Re-entry Heating Simulator in the 1960s. He subsequently left NASA, founded — in 1971 — a predecessor company that evolved into PTC, and used his NASA-acquired technological expertise as a departure point for developing a line of plasma torches and other equipment for industrial and research applications. PTC is now a well-established firm with an impressive list of customers in the U.S., Canada, Japan and several European nations.

Camacho sees further growth in industrial use of plasma heating systems because, he says, they "are among the most effective means for efficiently generating heat. They far surpass conventional methods because they offer greater temperature control, greater processing control, faster reaction time, lower capital costs and more efficient use of energy."

"The real benefits of plasma heating are just coming into focus," Camacho adds, suggesting that the technology might find even greater applicability in environmental applications than it has in industrial use. For example, the extraordinary temperatures available from plasma torches permit safe disposal of many types of toxic wastes by pyrolysis, the decomposition of hydrocarbons by the application of intense heat; municipal wastes are primarily hydrocarbons and plasma heating could convert them to harmless gases that could be recovered and used for fuel. The technology offers similar potential for disposing of medical wastes or for preventing the heavy metals in incinerator ash from leaching into underground water sources by vitrifying them, converting them into a glassy, rocklike substance that does not leach into soil.

Salvador Camacho and colleague Dr. Louis J. Circeo, formerly with Georgia Tech Research Institute and now with PTC, are engaged in demonstrating a number of advanced applications of plasma heating technology, including pyrolysis/vitrification of contaminated wastes. They have contracted with the Army Corps of Engineers for demonstrations involving destruction of hazardous asbestos wastes being removed from government buildings; plasma torching melts the asbestos fibers, which are subsequently solidified into a chemically inert, non-hazardous solid material. Camacho and Circeo are additionally negotiating projects that will demonstrate plasma heating procedures for the disposal of chemical weapons, dangerous chemicals and radioactive waste.



*At Chapparell Steel, Midlothian, Texas, plasma torch technology enables a "mini-mill" (above) to produce specialized steel in small batches, a competitive advantage. Below, Dr. Salvatore L. Camacho demonstrates use of a plasma torch; his company and its whole product line are based on NASA plasma torch technology.*

# Metal Coatings

Industrial Productivity and Manufacturing Technology

In the early days of the space program, General Magnaplate Corporation, Linden, New Jersey conducted a study for NASA of Apollo spacecraft hardware requirements that included development of a quality control program and a handbook. During this work, the company reported that conventional lubrication processes would not be adequate for some of the new, lightweight metals being used in Apollo components — titanium and magnesium, for instance — because the lubricants would "outgas" or boil away in the vacuum of space and leave hardware surfaces unprotected.

Under NASA contract, General Magnaplate developed several process techniques for bonding dry lubricant coatings to space metals; not susceptible to outgassing, the Magnaplate-applied coatings offered enhanced surface hardness and superior resistance to corrosion and wear.

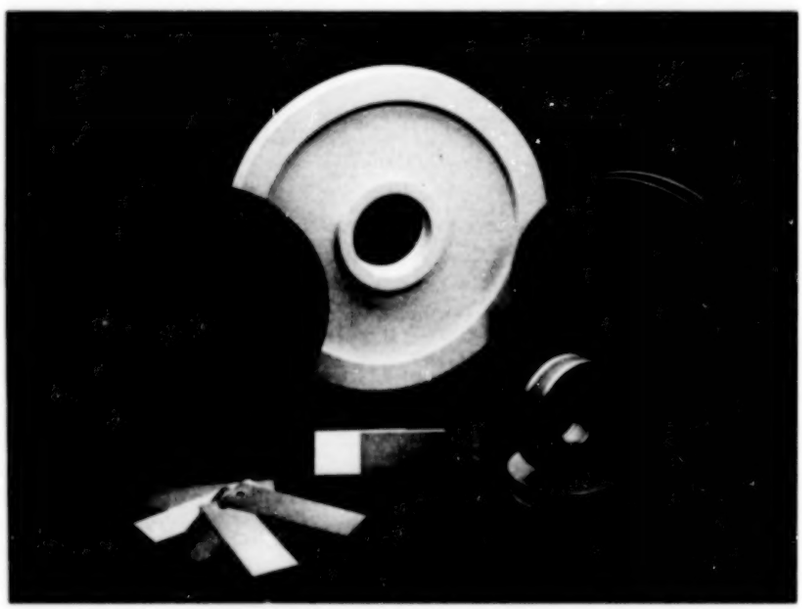
That work sparked a large scale expansion of the company's business and led to its establishment as a leader in development of high performance metallurgical surface enhancement coatings — "synergistic" coatings, they are termed, because the coated surface is superior in performance to the base metal or to the individual components of the coating.

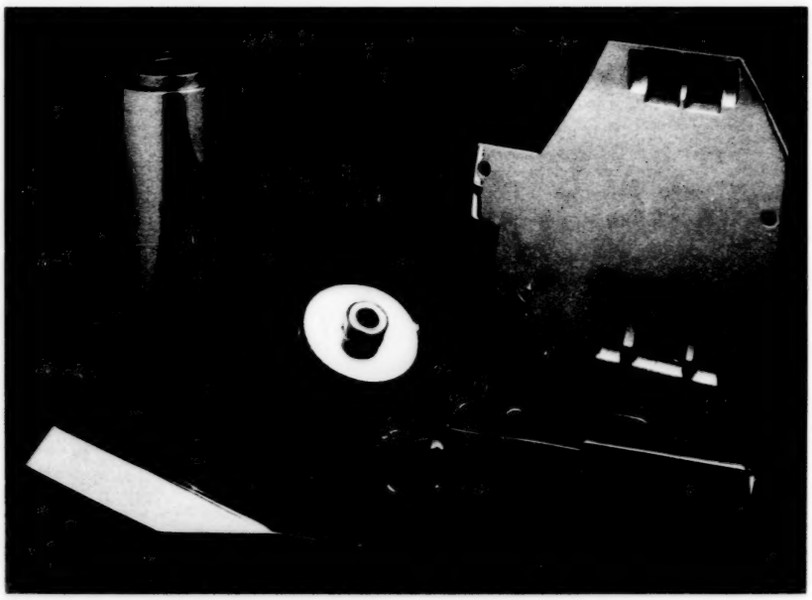
Initially applied to components of the Apollo spacecraft, the Magnaplate coatings have since been applied to virtually every NASA spacecraft. But the technology proved to have even broader utility in industrial operations and today Magnaplate-applied synergistic coatings are used in a wide spectrum of applications ranging from pizza making to laser manufacture, including machinery used in production of hundreds of household products, food processing machinery, pharmaceutical production machinery, equipment for printing and papermaking, cosmetic and cigarette manufacture, computers, turbines, pumps, valves and a great variety of other equipment.

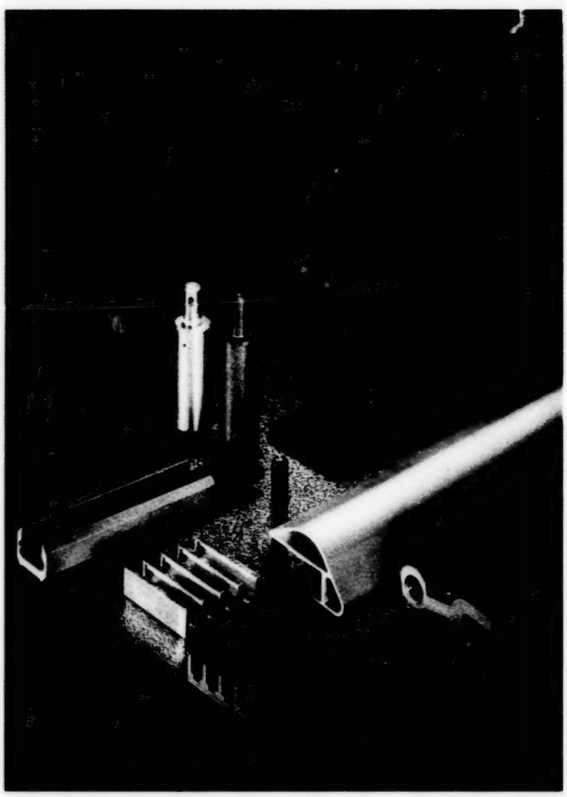
Magnaplate enhanced composite coatings are created in a multistep process. After the base metal is cleaned, it is thermally sprayed with engineered layers of ceramic particles. Then the layered ceramic matrix is infused with engineered polymers or other dry-lubricating particles/metals to create a dense, structurally integrated nonporous surface. This technique, says Magnaplate, surpasses conventional spray coating and provides a harder-than-steel, permanently dry-lubricated surface with superior corrosion resistance, wear resistance and easier mold release.

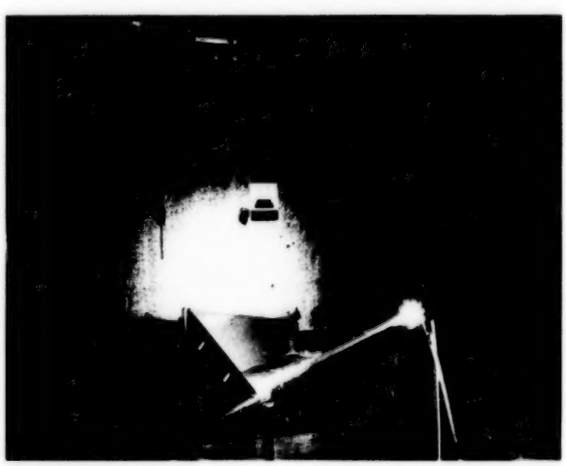
Magnaplate offers a variety of surface enhancement coatings, each designed to protect a specific metal or group of metals or to solve problems encountered under operating conditions. **Above,** General Magnaplate chairman and chief executive officer Charles P. Covino (right) and vice president/corporate director of operations Edward V. Aversenti, Jr. are shown at the Linden facility, one of five Magnaplate Materials Technology Centers, where the NEDOX® coating is being applied to air inlet vanes for a line of air moving equipment.

**At left** is a selection of parts coated with Magnaplate's new MAGNAGLOW™; originally designed for undersea and color-coding applications, MAGNAGLOW creates a hard, high-visibility fluorescent metal surface









that withstands up to 1,500 hours of salt spray testing. **Above** are a number of extruded and molded parts coated with TUFRAM®, a coating that offers unusually high levels of resistance to wear and corrosion. Metal parts treated with MAGNAPLATE HMF™ **(top right)** have a mirror-smooth ultrahard chromelike surface that, the company says, outwears chrome without the problems inherent in chrome plating.

In the **middle photo** is an example of a specific application: a synergistic coating on the steel piston and aluminum cylinder that make up Stone Bennett Corporation's remote shift device for trucks. In the **bottom photo** a technician is applying PLASMADIZE®, one of Magnaplate's newer coatings.

*NEDOX, TUFRAM and PLASMADIZE are registered trademarks of General Magnaplate Corporation.

™MAGNAGLOW and MAGNAPLATE HMF are trademarks of General Magnaplate Corporation.

# Motion Tracking System

Industrial Productivity and Manufacturing Technology

For future space operations, NASA is developing technology that would enable a robot resupply vehicle to automatically dock with and service Earth-orbiting satellites or the International Space Station.

As part of this program, NASA contracted with Integrated Sensors, Inc. (ISI), Utica, New York for development of a sensor system for controlling the robot vehicle during the critical docking phase. During this phase, the sensor and tracking system must sense the target satellite's relative motion and spin so that the robot vehicle can adjust its own motion to align with the satellite and slowly close until docking is accomplished.

ISI successfully developed the NASA system and then used the sensing/tracking technology as the basis of a commercial Object Position and Attitude Determination (OPAD) system that simultaneously tracks an object's linear and angular movement in all six degrees of freedom. Typical OPAD applications include analysis of human limb motion for physical therapy, assembly line position/motion analysis, video positioning of instruments and tools, auto crash dummy motion analysis, vehicle collision avoidance, robot control, process control, precision machining and surgical probe tracking.

Shown **below**, OPAD consists of a camera, a processor, a decal set and an optional video display. The decal is attached to the object to be tracked and the camera is trained on it; OPAD then automatically follows the object as it moves and provides position/attitude measurements. The system uses off-the-shelf components that can be specially configured for a specific application.

ISI also used the NASA technology as the basis for a spinoff Motion Analysis Workstation, a software package intended to simplify the whole process of video motion analysis. In many applications, high speed cameras are used to record the motion of objects of interest on videotape and the tapes are then digitized for further analysis on a computer. The tracked points' motion is then converted to user-specific information, such as the force acting upon a dummy during an auto crash test. The latter step requires manual identification of the points of interest in each frame of video data. ISI's Motion Analysis software obviates that laborious and time-consuming task by performing it automatically and accurately.

# Antenna Controller

**At right** is an R2000B antenna controller developed by Research Concepts, Inc. (RCI), Lenexa, Kansas with an assist from a NASA software package. A device that controls a dish antenna for tracking a communications satellite, the R2000B represents a significant advance in satellite location and tracking because it provides an accurate, cost-effective way to track satellites in inclined orbits; satellites in such orbits have historically been difficult —and therefore expensive — to track.

Geosynchronous satellites, such as those in the networks of commercial communications satellites, orbit Earth at a rate equal to the rate at which Earth rotates about its axis. Natural forces tend to cause the satellite's orbital plane to tilt, or become *inclined* — meaning inclined to Earth's equatorial plane. To keep the satellite "stationary" and prevent drifting, an on-board rocket thruster system executes stationkeeping maneuvers — East/West maneuvers to keep the satellite in its assigned orbital position and North/South maneuvers to hold the satellite in Earth's equatorial plane.

However, when a satellite's thruster propellant supply dwindles, technicians seeking to extend the satellite's life as long as possible may deliberately allow it to drift into an inclined orbit as a fuel-saving measure. The orbital change is accomplished by suspending North/South maneuvers while continuing the East/West maneuvers. The fuel saving and satellite life extension are of significant order because North/South stationkeeping normally expends 90 percent of the total propellant usage.

A satellite allowed to drift into an inclined orbit exhibits certain known characteristics. In developing the R2000B unit, RCI exploited these characteristics and additionally studied the satellite tracking techniques of a NASA computer program known as ASAP (Artificial Satellite Analysis Program), a general orbit prediction program originally developed by Jet Propulsion Laboratory.

The technology of the RCI tracking device, says company software engineer Steven Mikinski, affords substantial savings in inclined orbit tracking. RCI's use of the ASAP software, he adds, enabled company savings in avoiding duplicatory research and shortened the time needed to bring the R2000B to the marketplace.

ASAP was supplied to RCI by the Computer Software Management and Information Center (COSMIC)*, NASA's mechanism for making available to industry, academic and government clients computer programs, originally developed by government agencies, that have secondary utility (see page 128).

*COSMIC is a registered trademark of the National Aeronautics and Space Administration.

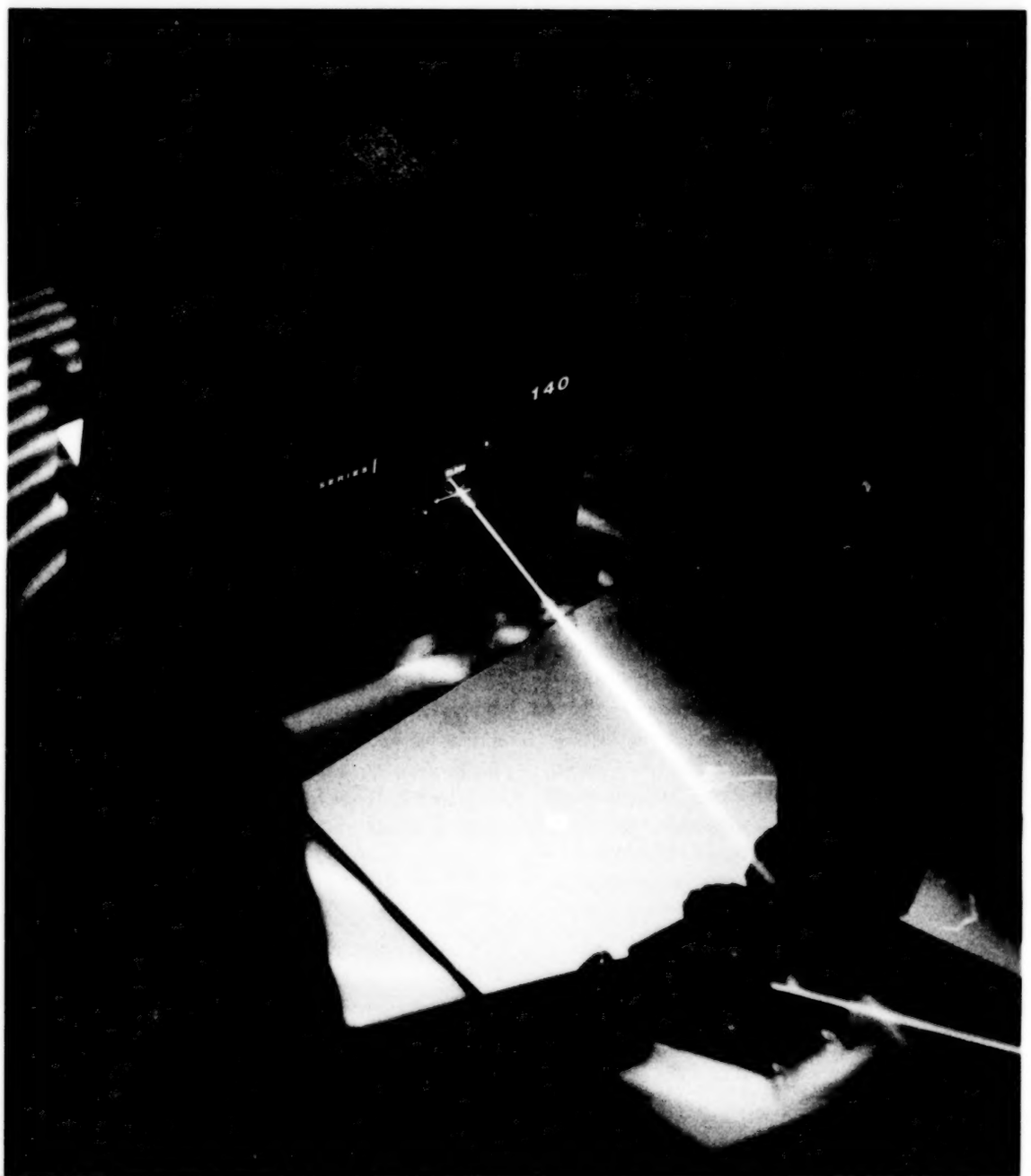
# Small Business Innovations

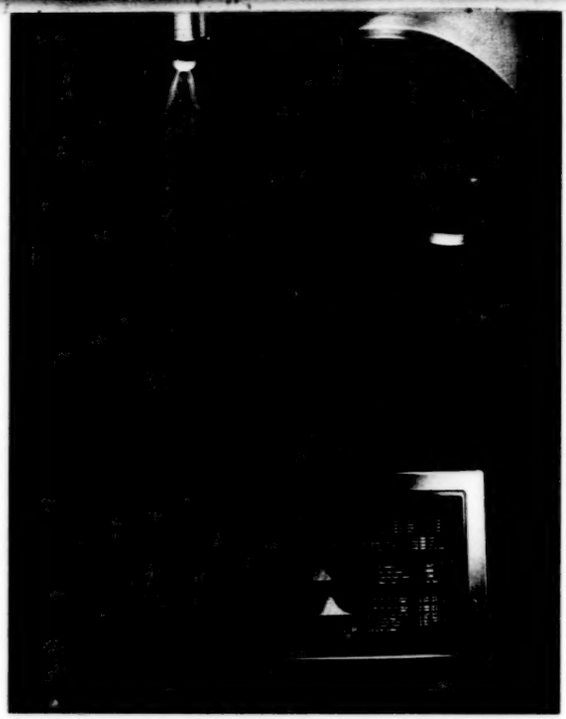
Industrial Productivity and Manufacturing Technology

Shown **below** is a Series 140 single frequency laser produced by Lightwave Electronics Corporation, Mountain View, California. It is a new member of a family of laser systems based on technology originally developed under a NASA Small Business Innovation Research (SBIR) contract.

The original contract with Jet Propulsion Laboratory called for development of a prototype laser-diode-pumped solid state transmitter. Lightwave delivered a low noise ring laser with wavelength tuning that could be used as a local oscillator in an optical communications network. The wavelength tuning feature allows "phase locking" two lasers, generating electronic frequencies, in the manner of radio and microwave electronic oscillators.

From this technology, Lightwave developed the commercial Series 120/122, Series 123 and the Series 140 lasers, which have applications in fiber optic communications, difference frequency generation, fiber optic sensing and general laboratory use. They feature a patented resonator design known as NPRO (nonplanar ring oscillator).





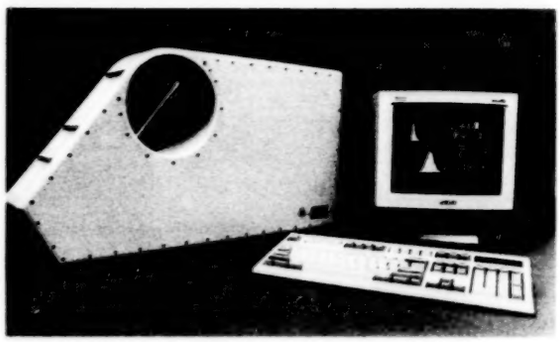
The combination of NPRO and laser diode pumping, says Lightwave, offers "greater reliability, smaller size and superior performance compared to conventional lamp-pumped products."

Established by Congress in 1982, the SBIR program is designed to increase small business participation in federal high technology R&D activities and to stimulate conversion of government-funded research into commercial application; it has generated spinoff applications in about one of every three projects approved for funding from proposals submitted by small businesses.

A second example of an SBIR spinoff is the Phase Doppler Particle Analyzer (PDPA) developed by Aerometrics, Inc., Sunnyvale, California as an offshoot to an SBIR contract with Lewis Research Center. The PDPA, shown **above** conducting a spray characterization test, is a non-disruptive, highly accurate laser-based method of determining particle size, number density, trajectory, turbulence and other information about particles passing through a measurement probe volume. The system consists of an optical transmitter and receiver, a signal processor and a computer with software for data acquisition and analysis.

Velocity and size data are inferred from particles that are carried within the flow field being studied. Velocity profiles are obtained by analyzing the Doppler difference frequency of light scattered by particles passing through the intersection of two laser beams. Particle diameter is determined by measuring the phase difference between three detectors positioned a known distance from each other.

Aerometrics offers a variety of PDPA systems for different applications. A major application is spray characterization for various sprays and spray generators, such as paint, agricultural, fire sprinkler and fuel sprays; electrohydrodynamic flows; atomizers and spray nozzles. The PDPA also has utility in combustion, aerodynamic and underwater research studies.



A related product stemming from the same SBIR work is Aerometrics' Microsizer **(above)**, an adaptation of PDPA technology for medical equipment manufacturing and analysis of small sprays, nebulizers, aerosols, mists and other contained flows. Developed for a customer producing metered dose inhalers (MDIs), the Microsizer provides discrimination between propellant and medicine by determining the size of particles emitted and their concentrations, information important to quality assurance.

A third example of SBIR commercialization is the work of Millitech Corporation, South Deerfield, Massachusetts. Millitech specializes in high frequency components and subsystems operating in the upper portion of the millimeter wave (MMW) frequency range, from 30 to 700 gigahertz; this is an area where the commercial state of the art is limited and Millitech has focused on this area to carve a business niche by developing a broad line of high performance, readily-available products.

Millitech has conducted a number of NASA SBIR projects, principally with Jet Propulsion Laboratory, and this work has generated several commercial MMW products; a sampling is shown **at right.** Millitech considers its most important contributions to be in quasi-optical components and active components. In particular, the company has advanced the state of the art in sensitive receiver technology by developing very high performance mixers and multipliers.

Although the principal market is the scientific research community, Millitech high frequency components are finding practical applications beyond laboratory use. They are generally used in receivers and transceivers for such applications as monitoring chlorine monoxide, ozone, water vapor and other atmospheric compounds; in radioastronomy; in plasma characterization; and in material properties characterization.

ORIGINAL PAGE
COLOR PHOTOGRAPH

# Machine Monitor



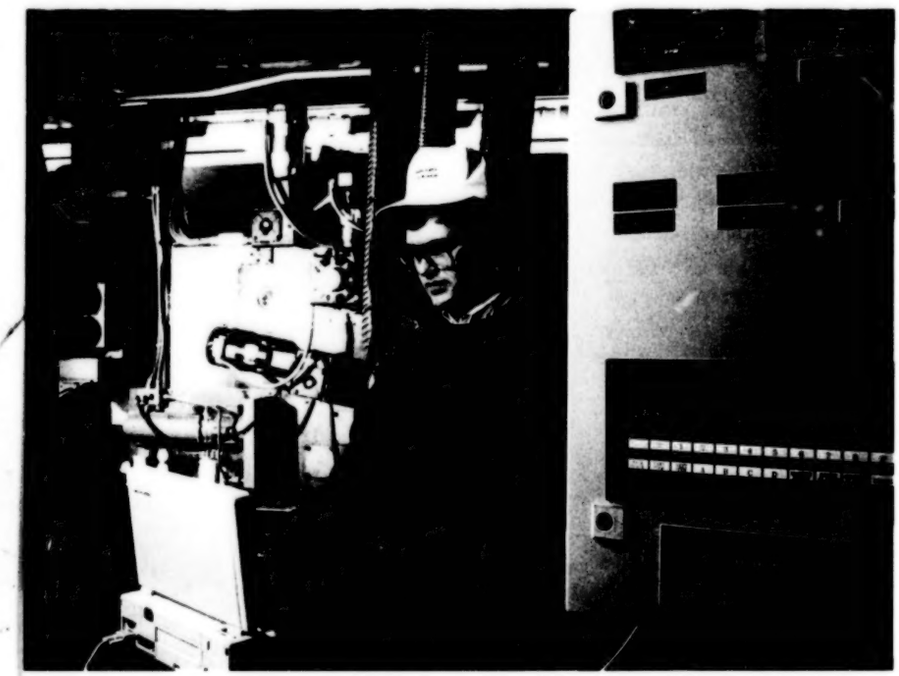
*NASA Tech Briefs* is a monthly publication that advises its 200,000 industry/government subscribers of recent technological advances and technologies available for transfer (see page 129). The publication has been the source of a great many technology transfers; often it serves as a problem-solving tool, sometimes as a technological lead or inspiration that sparks development of a new product or process.

An instance where *Tech Briefs* information triggered both a problem solution and a new system is the experience of *Tech Briefs* subscriber G. W. Shelton, a design engineer with Logical Control Systems (LCS), Toledo, Ohio. Shelton was assigned the task of solving a problem for James River Corporation, Perrysburg, Ohio. James River is an international leader in the food packaging industry and also a major producer of paper; the company prints and die-cuts paperboard packaging products for the food processing industry.

James River had a problem involving jamming of the printing presses used for manufacturing packaging products. Jamming was a relatively rare occurrence but one of great concern because of the extensive damage to the machinery caused by jamming; repairs can be very costly and down time/loss of production adds considerably to the cost. The company wanted to know if there was a way to detect the onset of machine jam and automatically shut down the press faster than an operator could to limit or eliminate damage to the machine; avoidance of one serious jam could easily pay for the investment in special monitoring equipment.

While considering possible solutions, Shelton chanced upon a *Tech Briefs* article that described a system of motors, pulleys and belts developed by Goddard Space Flight Center to rotate a large space radiometer for measuring cosmic background radiation. The article included a diagram of the pulley and belt drives that started Shelton thinking of a new line of approach: a system that monitors the drive components for subtle changes in relative speed that would indicate belt slippage and the probability of a machine jam.

Using this approach, Shelton and LCS developed a prototype machine monitor and tested it at the James River plant. A year of testing and refinement of the design led to development of a second generation LCS-1010 System Monitor, which monitors a variety of variables such as speed, motor current, motor voltage and assorted digital inputs. When the proper combination of variables is not met, the system sends an emergency "Stop" signal to the press and simultaneously triggers an alarm. The LCS-1010 was successfully field tested in 1992 and ordered into production; first production units were delivered at yearend 1993. In the accompanying **photo**, a James River engineer is reviewing a printout of the system's data, an aid to preventive maintenance; in right foreground is the LCS-1010 control box with its monitoring displays.



# Piping Connector

In developing its Component Test Facility (CTF), where NASA tests rocket engine components, Stennis Space Center (SSC) encountered a problem. In the design phase of the CTF's development, it was originally planned to use conventional clamped connectors on the CTF piping lines that carry rocket propellants and other gases.

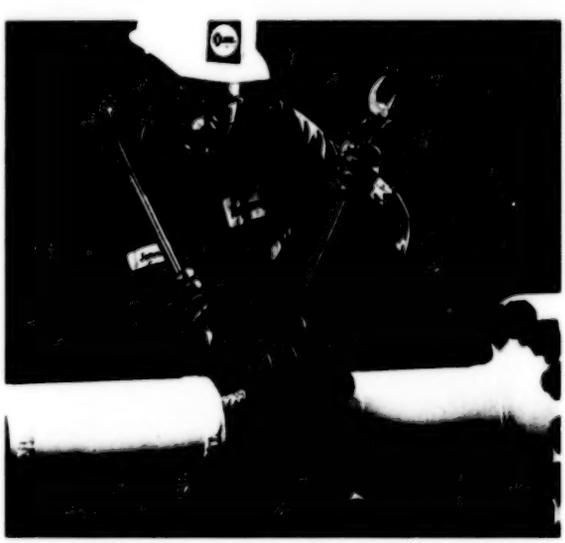
But Marshall Space Flight Center, which has broad experience with similar connectors, advised that clamped connectors were not suitable for use on lines that carry high pressure cryogenic (extremely low temperature) fuels; the connectors had been known to leak when the propellant lines were chilled to a pretest temperature of 400 degrees below zero Fahrenheit.

SSC decided to develop a new connector and selected Reflange* Inc., Houston, Texas to handle the job. Reflange adapted one of its existing designs to include a secondary face seal more tolerant of severe temperature changes. After testing and refinement, the company produced a connector that solved the problem. Known as the T-Con*, it was used in all CTF locations where severe thermal shock was anticipated.

That task for NASA led to not one, but two, Reflange spinoff products, one of them a commercial T-Con with the secondary seal for thermal shock applications in industrial operations. The second spinoff emerged in the course of T-Con development, when designers realized that, because of the limited need for a large, specialized clamp set in exotic materials, the cost was high.

Reflange looked for other options and came up with the E-Con* dual seal flange design. The E-Con **(above)** offers all the technical advantages of the T-Con but at a reduced cost in larger sizes where quantities required are small. The E-Con features pressure and temperature ratings identical to those of the ANSI standard for comparable flanges, but in higher pressure classes the E-Con offers a smaller more compact design with weight savings up to 79 per cent. The E-Con has been added to the Reflange commercial line.

*Reflange, T-Con and E-Con are registered trademarks of Reflange, Inc.



# Analysis Software



**Below** is a computer generated image that provides an analyst a great deal of information as to how a part of a mechanical system will bear up under stress. It was created by a new method of analyzing components, from aircraft and combustion engines to electric shavers and automotive parts.

Known as GPBEST (General Purpose Boundary Element Solution Technology), the software package is a commercial derivative of a computer code originally developed under NASA sponsorship, distributed by Boundary Element Software Technology Corporation, Getzville, New York. As its name indicates, GPBEST employs the boundary element method (BEM) of mechanical engineering analysis, as opposed to finite element analysis (FEA), the dominant method. Although BEM theory dates back almost a century, it had shortcomings that stunted its commercial development until recently, when the advent of advanced, powerful computers and advances in linear algebra elevated BEM to its status as a cost-effective alternative to traditional analysis methods.

"Use of the boundary element method will result in less expensive products because it allows them to move more quickly from the design stage to manufacturing," says Dr. Prasanta K. Banerjee, professor of civil engineering at SUNY/Buffalo (State University of New York at Buffalo) and leader of a NASA-funded research project that explored BEM in the mid-1980s. The boundary element method, he states, is 10 times faster in data preparation and more accurate than the FEA approach most companies use.

BEM functions on the premise that any region of a system's volume may be analyzed by being subdivided into sections consisting only of surfaces — rather than three-dimensional elements. By calculating the surfaces, predictions can be made about a system's internal behavior, so BEM in effect solves three dimensional volume problems as two dimensional surface problems; In this manner, a thorough analysis can be obtained in a fraction of the time normally required.

The GPBEST software stemmed from a technology foundation created in a research effort initiated in 1982 by Lewis Research Center. NASA funded BEM research by Pratt & Whitney division of United Technologies and Dr. Banerjee's SUNY/Buffalo group. A significant product of that research was the BEST 3D (Boundary Element Solution Technology in Three Dimensions) computer code. Although BEST 3D was a "research level" code, it generated wide interest in the computational mechanics community because of its breakthrough potential for solid and structural mechanics applications, so NASA released BEST 3D publicly.

There remained a clear need for a commercial derivative software product. Beginning in 1989, Dr. Banerjee developed the commercial GPBEST and founded BEST Corporation to market it. The software is in wide use for solving such problems as stress analysis, heat transfer, fluid analysis and the yielding and cracking of solids. GPBEST is being used by Deere & Company to design tractor parts, by Mercedes Benz and General Motors for auto parts, by Pratt & Whitney for aerospace parts, Braun for household appliances and Nissan for acoustic analysis.

# Emergency Lighting System

Landmark Plastic Corporation, Akron, Ohio is a manufacturer of plastic trays, packs, pots and other specialty horticultural products for customers in the U.S. and abroad. Landmark's Maintenance Department reports that technology in a *NASA Tech Briefs* (see page 129) article provided an important cost-reducing, safety-enhancing benefit through improvement of the company's emergency lighting system (ELS).

Landmark's main factory lighting consists of banks of 400 watt 277 VAC mercury vapor bulbs **(right)**. When a power outage occurs, two ELS sets take over. One is the standard low watt battery system; the other is composed of 120 VAC incandescent lamps that come on automatically when one leg of the mercury vapor main factory lighting is lost.

Landmark had a problem with this system. When a power outage occurred, it took seven to 12 minutes for the primary mercury lamps to cool down before they would relight. In addition, it took two to seven minutes for the 120 VAC 200 watt ELS incandescent lamps to activate. That meant that there was a period of as much as seven minutes before production could resume, a period during which the light supplied by the low watt battery system was so dim that lights mounted on forklifts were used to illuminate the production area.

Steve Keller of the Maintenance Department was asked to design and build an ELS panel that would allow the 120 VAC incandescent lights to come on instantaneously after a power outage, permitting immediate resumption of production. Keller is pictured **below** working on his design.

Keller's solution was a system wherein the 120 VAC bulbs are activated by any loss of voltage in the 277 VAC main lamp circuit, coupled with photosensing devices used to keep the ELS on until the 277 VAC primary mercury lamps reach full brightness. Keller credits *NASA Tech Briefs* with an assist; he learned about the capabilities of photosensing devices from a *Tech Briefs* article on photodetector technology developed at Marshall Space Flight Center.

The new system is in place and the Landmark plant is safer because there is no longer a period of dim light and more productive because production is resumed more quickly after a power outage, and in manufacturing operations time is literally money.

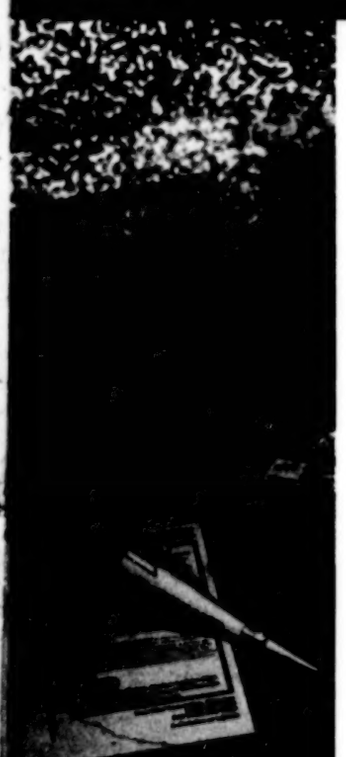

NASA
TEACHER
RESOURCE
CENTER
THE
FEDERAL
LABORATORIES
DATABASE

# Technology Transfer

*A description of the mechanisms employed to encourage and facilitate practical application of new technologies developed in the course of NASA activities*

# Putting Technology to Work

A nationwide technology transfer network seeks to broaden and accelerate secondary application of NASA technology



Because they are challenging and technologically demanding, NASA programs generate a great wealth of advanced technology. This bank of technology is a national asset that can be reused to develop new products and processes to the benefit of the U.S. economy in new companies, new jobs and resulting contributions to the Gross National Product.

Such "spinoff" applications do not happen automatically. It takes a well-organized effort to put the technology to work in new ways and to reap thereby a dividend on the national investment in aerospace research.

NASA accomplishes that end by means of its Technology Transfer Program, which employs a variety of mechanisms to stimulate the transfer of aerospace technology to other sectors of the economy. The program is managed by the Commercial Development and Technology Transfer Division of NASA's Office of Space Access and Technology. Headquartered in Washington, D.C., the division coordinates the activities of technology transfer offices located throughout the United States.

A relatively new program mechanism, initiated in 1993, is the NASA Technology Commercialization Center Program, a three-year experiment designed to facilitate the commercialization of NASA-developed technologies. NASA concluded a cooperative agreement with the $IC^2$ Institute of The University of Texas at Austin (UT) whereby $IC^2$ would establish and manage two technology commercialization centers, facilities intended to speed the commercialization of NASA technology by U.S. industrial firms in the interest of advancing American competitiveness.

The technology commercialization process involves creating and incubating new and emerging businesses around NASA technologies, and licensing technologies to existing medium and large companies with established manufacturing and marketing channels. Located at Ames Research Center and Johnson Space Center, the new facilities are the Ames Technology Commercialization Center (Ames TCC) and the Johnson Technology Commercialization Center (Johnson TCC). An Austin-based professional staff supports the two field-based sites in the areas of market research and licensing, support of TCC companies, and a variety of project management activities. The Austin team has the ability to identify new commercial markets for NASA-developed technology by conducting extensive market and industry analysis. Market size, nature of competition, product pricing and positioning and industry trends are key factors in the analysis.

$IC^2$ was selected to manage the test program because of the institute's success in operating a similar incubator in Texas. Incubation is the process of finding companies willing to invest in new ventures that involve taking a technology developed by a university or a government agency and turning it into a commer-

cial product. The institute has for several years operated the Austin Technology Incubator, which has worked with UT and economic partners in the Austin area to create new firms and new jobs from research conducted by UT, R&D consortia and other technology sources.

$IC^2$ is applying the laboratory-to-market expertise it acquired in managing the Austin incubator to the Ames and Johnson test centers, pairing the technology generated at the two NASA field centers with appropriate partners in the business and financial communities of southeastern Texas and California's San Francisco Bay Area.

At Johnson TCC, much of the expected technology commercialization will involve software, engineering and medical science because of Johnson Space Center's role as the human space flight center. In California, the focus for the Ames TCC is expected to be materials, computing software and hardware, and selected areas of medical application, using the capabilities of the Silicon Valley industrial complex to support and commercialize Ames' technologies.

*In the photo, entrepreneur Prasanna Shah (center) explains the components of his wireless communications products to Geoffrey Lee of the Ames Research Center Office of Commercial Technology and Mary Livingston, technology manager of the Ames Technology Commercialization Center. The Ames TCC and a companion Johnson TCC include newly created "technology incubator" facilities intended to speed the commercialization of NASA technology by U.S. industrial firms.*

The two centers were selected because of the broad variety of technologies being developed by each and their existing business and economic infrastructures. Because Ames TCC and Johnson TCC represent different types of technology development focus, and because they reside in very different economic and social environments, NASA feels that if the test projects are successful the two centers could serve as models for extending the concept to other NASA centers and possibly to federal laboratories outside the NASA complex.

In addition to the commercialization centers, other mechanisms employed in the Technology Transfer Program include a network of technical assistance centers that provide, to government and industry clients, access to a great national data bank; technology transfer officers, located at each of NASA's field centers, who serve as regional managers for the program; applications engineering projects, in which NASA collaborates with public sector or industrial organizations to develop innovative solutions to major problems through redesign or reengineering of NASA technology; a software center that offers computer programs applicable to secondary use; and a publication that informs potential users what technology is available for transfer. These mechanisms are detailed in the following pages.


# Technology Transfer Network



To promote technology transfer, NASA operates a number of user assistance centers whose job is to provide information retrieval services and technical help to industrial and government clients.

Intended to meet the technological needs of American industry and boost U.S. competitiveness, the National Technology Transfer Network is composed of a National Technology Transfer Center (see page 122) and six regional Technology Transfer Centers (RTTCs). The RTTCs are geographically located to provide an equal distribution of services throughout the country. The regional deployment of the centers and their alignment with the Federal Laboratory Consortium, allows the RTTCs to work closely with federal, state and local programs in serving the technology-related needs of business and industry.

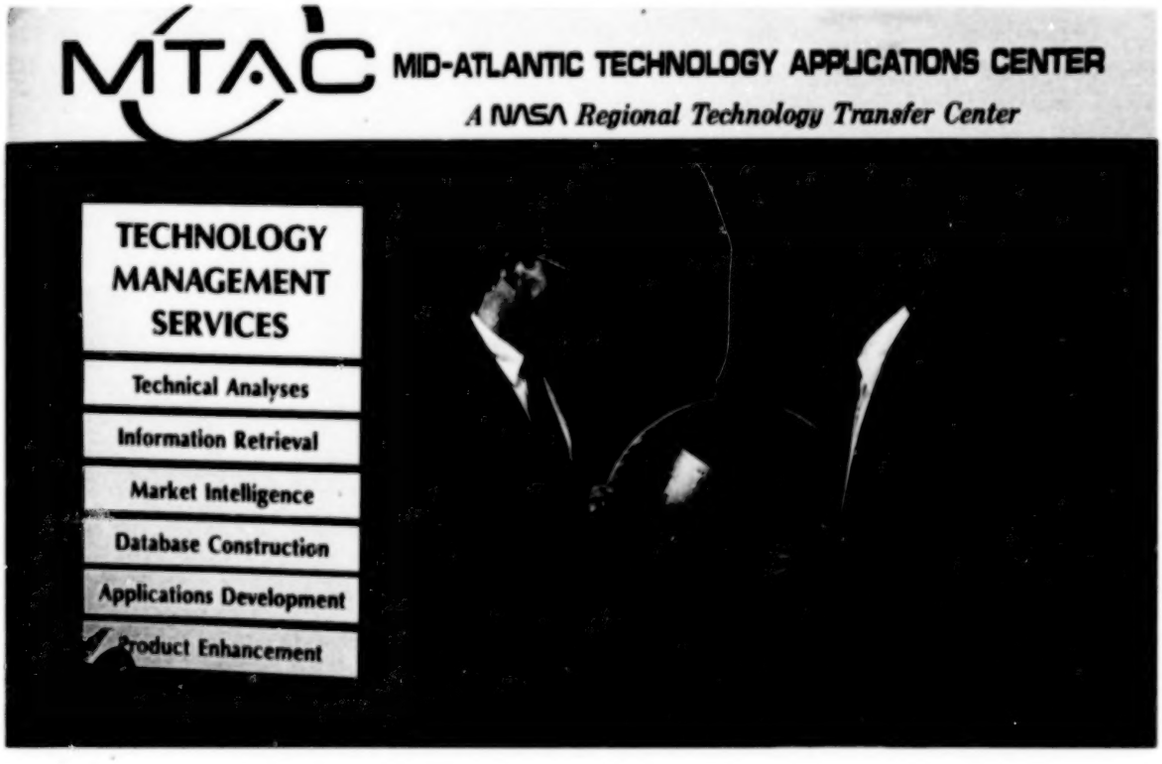
The RTTCs provide value-added services to meet the needs of clients, including:

- Information services: computerized searches of federal technology databases and other technology sources.
- Technical services: assessment of technology requirements, analysis of technology applications, and engineering reports.
- Commercialization services: technology brokering, business analyses and venture capital sourcing.

Other elements of the National Technology Transfer Network include:

- Federal agency technology transfer programs and activities.
- State and local agencies and their programs, such as technology centers and business/technical assistance centers.
- Business and industry consortia, associations and communities. The photo **below** illustrates one of the most effective ways in which the RTTCs seek out contacts in the business community, through booth contacts at trade shows.

A typical RTTC provides a wide range of technology management services, including information retrieval **(right)**, technical analyses and assessments, market intelligence, product enhancement and applications development. The center conducts searches in a wide variety of commercially available government and proprietary databases to provide information on state-of-the-art developments in a particular field, individuals and organizations conducting relevant R&D, patents and licenses, and technologies that can be redeployed or reengineered to meet a client's needs.

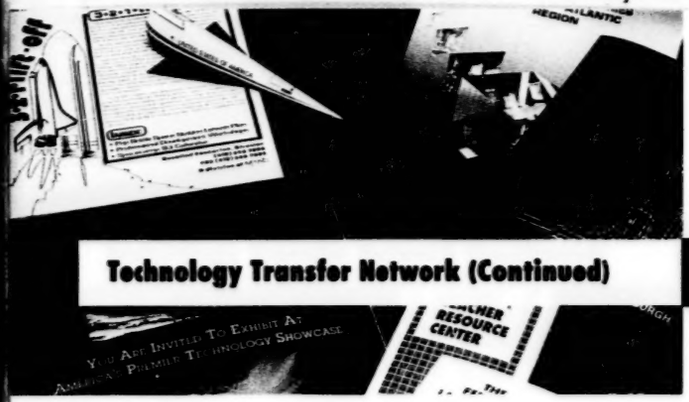


After searching the databases, the RTTC investigates noncomputerized sources of materials such as traditional print materials. Experts from NASA field centers, federal laboratories, universities and industrial organizations are contacted to locate additional information.

The RTTCs support NASA's educational objectives by providing teachers access to information generated by NASA programs. The center makes available scientific and technological materials related to research and technological developments in the areas of life sciences, physical science, astronomy, energy, Earth resources, geology, mathematics, astronautics and space flight. At **right**, an RTTC staffer at a Teachers Resource Center helps a teacher search for materials to enliven lesson plans. At **lower right** is a sampling of published materials available to teachers and other clients of the RTTCs.

(Continued)


ORIGINAL PAGE
COLOR PHOTOGRAPH



## Technology Transfer Network (Continued)



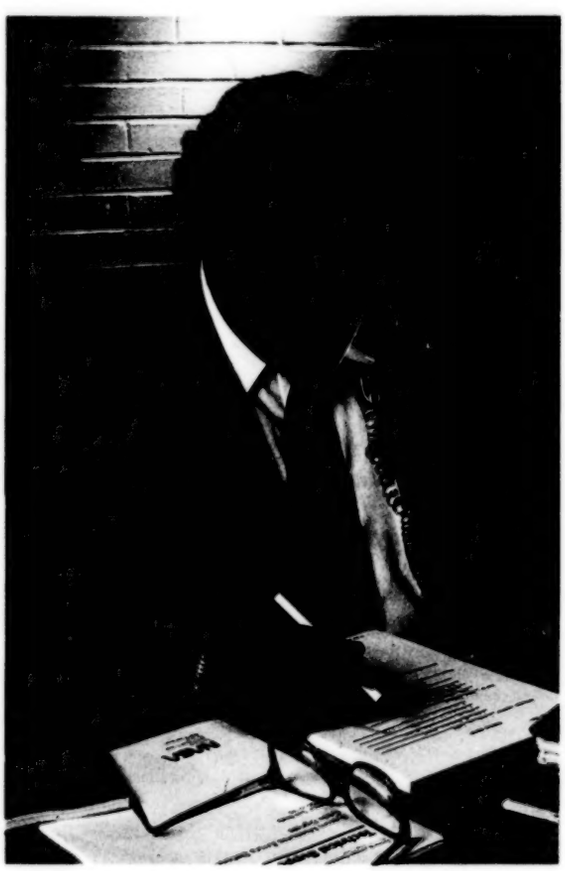
The hub of the National Technology Transfer Network is the National Technology Transfer Center (NTTC), located at Wheeling Jesuit College, Wheeling, West Virginia. Now in its development phase, the NTTC is intended to serve as a clearing house for federal technology transfer, linking U.S. firms with federal agencies and laboratories, the RTTCs, and state and local agencies.

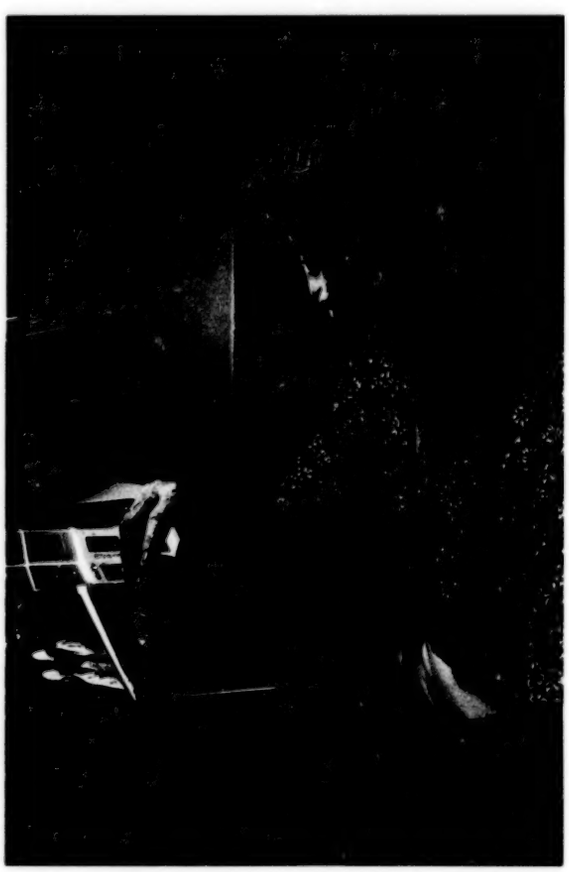
One of the center's first steps in the interest of enhanced U.S. competitiveness was establishment of a "gateway service," a toll-free telephone access to a full federal technology database and indexing system. By calling a 1-800 number, U.S. companies can access the federal laboratory system in search of technologies and research data that can assist them in developing their businesses.

The NTTC also provides training and educational services to government and industry to develop the skills essential to effective technology transfer. Additionally, the center conducts outreach and promotional activities to improve private sector awareness of technology transfer opportunities.

One such activity is NTTC's national electronic bulletin service for both the public and private sectors of the U.S. technology transfer community. The free service includes notices of upcoming technology transfer related meetings, announcements of new technologies, problem query/answer communications, success stories and posting of opportunities.

Support of all the elements of the National Technology Transfer Network is provided by the Technology Transfer Office at the Center for AeroSpace Information (CASI). This office executes a wide variety of tasks, among them maintenance of the subscription list for *NASA Tech Briefs*, the principal tool for advising potential users of technologies available for transfer; maintenance and mailout of Technical Support Packages (TSP), which provide details of new technologies, involving a reproduction effort of more than 1.5 million pages annually; and responding to requests for information, an activity that entails processing of some 60,000 letters and other inquiries and mailout of more than 300,000 docu-

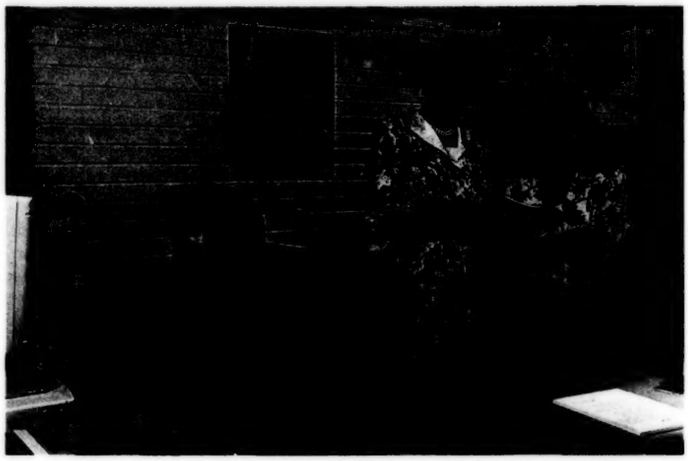




ments a year. The office additionally serves as a "help desk," channeling information seekers to the proper agency or organization when the information is not available at CASI.

Pictured at **far left** is Walter M. Heiland, manager of the CASI Technology Transfer Office. **Near left**, senior technology associate Jane Lynn-Jones is reviewing photographs to determine their suitability for publication in NASA's *Spinoff*. **Above**, Bobbi Ebberts (left) and Mary Crum are processing TSP packages requested by clients. At **right**, Diane Odachowski (left) is preparing correspondence and Sharleen Angyelof (center) and Lenora Parris are conferring on a statistical analysis of the types of information being requested. **Below**, Maria Zimmerman (seated) and Katherine Wenerick are preparing responses to inquiries.

The CASI Technology Transfer Office is also responsible for research, analysis and other work associated with this annual *Spinoff* volume; for distribution of technology transfer publications; for retrieval of technical information and referral of highly detailed technical requests to appropriate offices, for developing reference and bibliographical data; and for public relations activities connected with media, industry and trade show interest in technology transfer matters.




# Technology Transfer Officers



An important element among the NASA mechanisms for accelerating and broadening aerospace technology transfer is the Technology Transfer Officer, or TTO. TTOs are technology transfer experts at each of NASA's nine field centers and one specialized facility who serve as regional managers for the Technology Transfer Program.

Representative of the group is Rick Galle, TTO at Stennis Space Center (SSC); **Below**, Galle (blue tie) and SSC Director Roy S. Estess are reviewing literature designed to assist in the dissemination of center developed technologies.

The TTO's basic responsibility is to stay abreast of research and development activities at his center that have significant potential for generating transferrable knowledge. He assures that the center's professional people identify, document and report new technology developed in the center's laboratories and, together with other center personnel, he monitors the center's contracts to see that NASA contractors similarly document and report new technology, as is required by law. This technology, whether developed in-house or by contractors, becomes part of the NASA bank of technology available for secondary application.

To advise potential users of the technology's availability, the TTO evaluates and processes selected new technology reports for announcement in NASA publications and other dissemination media. Prospective users are informed that more detailed information is available in the form of a Technical Support Package.

The TTO also serves as a point of liaison among industry representatives and personnel at his center, and between center personnel and others involved in applications engineering projects, efforts to solve public sector problems through the application of pertinent aerospace technology. On such projects, the TTO prepares and coordinates applications engineering proposals for joint funding and participation by federal agencies and industrial firms.

Among application projects conducted by SSC recently is one involving use of NASA technology to enhance ultrasound monitoring of fetuses during preg-

nancy, a project undertaken jointly with the non-profit Louisiana Pregnancy Institute, Slidell, Louisiana. Dr. Jason Collins, founder and president of the institute, was looking for a way to clear up some of the cloudiness, or "noise," commonly found in ultrasound images, in order to be better able to see a baby's umbilical cord. SSC software engineer David Walters applied NASA image enhancement technology and created an interactive computer program of filters to apply to the ultrasound imagery; the filters clear much of the noise from the imagery. **Above** are obstetrician Collins (left), engineer Walters (center) and TTO Galle.

Other work at SSC includes support of technology transfer agreements with the states of Mississippi and Louisiana, which includes such activities as participation in economic development-related events, technology transfer workshops, and certain small scale projects with industrial firms. For example, Real Inspection Services, Moss Point, Mississippi sought assistance in qualifying company employees for non-destructive testing; SSC helped set up and execute a training program. Electro National Corporation, Canton, Mississippi sought to identify new, high technology products to manufacture in the company's existing facility; SSC engineers located several new product candidates. General Motors, Shreveport, Louisiana needed a non-destructive test method to inspect resistant spot welds and GM requested information on production test equipment capable of inspecting

one weld a minute; SSC identified the equipment.

SSC also supports the new Mississippi Enterprise for Technology Inc. (MSET), a non-profit organization established to enhance the creation and growth of technology-based Mississippi industries. **Above**, visiting Mississippi Congressman Gene Taylor **(center)** discusses MSET activities with Mississippi businessman Dan Lee (standing) and Cecil Mills of SSC's Center of High Learning.

# Technology Applications

Technology Transfer

Applications engineering projects are efforts in which NASA seeks to solve significant public sector or industrial problems through redesign or reengineering of existing technology. They originate in various ways. Some stem from requests for assistance from other government agencies; others are generated by NASA technologists who perceive possible solutions to problems by adapting NASA technology to the need. NASA also employs an applications team composed of scientists and engineers representing different areas of expertise, who identify problems, submit them to NASA centers for review, then assist the centers in adapting solutions.

An example of an ongoing applications engineering project is an effort at Johnson Space Center (JSC) to develop a ventricular assist device (VAD) in cooperation with Baylor College of Medicine, Houston, Texas. A VAD is a device intended to boost the heart output of patients with deteriorated cardiac functions.

For many such patients, a heart transplant is the best alternative, but because the number of patients needing transplants far exceeds the availability of donor hearts, transplantation requires a long waiting period. During the long wait, a patient's condition often deteriorates further, complicating both preoperative and postoperative care. Because of these factors, there is a great deal of research under way toward development of an advanced, implantable VAD that could serve either as a bridge-to-transplant device or as a permanent heart assist device.

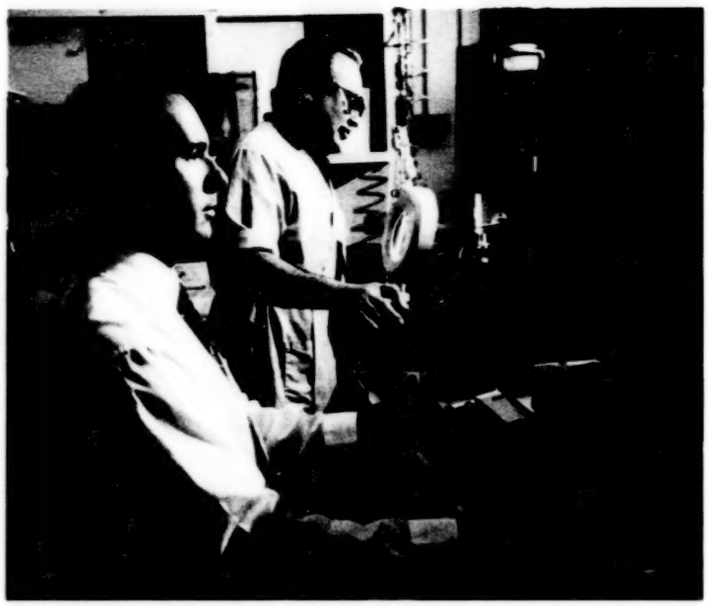
The NASA/Baylor effort traces its origin to 1984, when a JSC engineer, David R. Saucier, received a heart transplant under the care of internationally famed heart surgeon Dr. Michael DeBakey and Baylor physician Dr. G. P. Noon. Saucier started the VAD development effort, backed by a small group of volunteers from JSC and Baylor, the JSC engineering directorate and Dr. DeBakey. In 1992, the group received NASA funding to elevate the project to a higher level of effort.

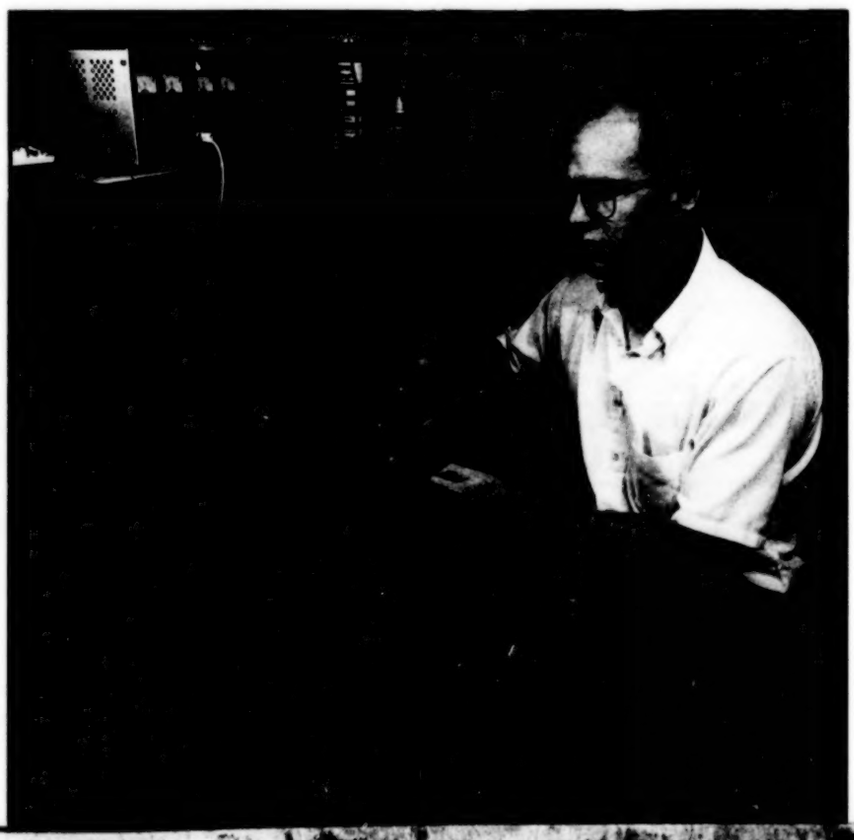
A key requirement for an implantable VAD was a high degree of miniaturization; the device had to be small enough to be implanted in young children. Where most prior temporary VADs had employed pulsatile diaphragm centrifugal pumps, JSC decided that a continuous axial pump was the design most likely to meet all criteria while maintaining a relatively low production cost. One of the pump's components, the inducer, is based on Space Shuttle Main Engine technology; its job is to boost the flow of blood.

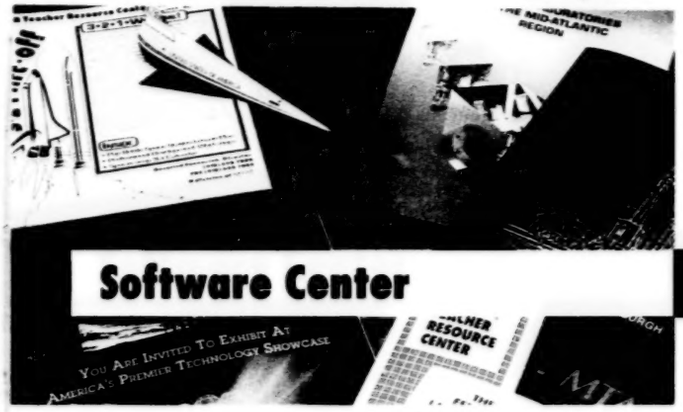
The JSC/Baylor team, through extensive testing and redesign, was successful in developing a device able to solve the major problems of pump miniaturization, efficiency, and the ability to prevent hemolysis (damage to red blood cells). In 1993, the group initiated testing of the device on animal subjects (calves).

Shown at **far left**, the NASA/Baylor VAD is 2.5 inches long and one inch in diameter; its inducer/impeller, less than half an inch in diameter, rotates between 10,000 and 15,000 revolutions per minute, depending on the required pump output. At **left**, JSC's Greg Aber (seated) and Dr. Kazumi Mizuguchi of Baylor College of Medicine are measuring the extent of red cell damage caused by the pump; **below** George Damm, Baylor, is conducting a test of the VAD drive motor; and at **right** Robert Benkowski (at console) and Juan Fernandez, both of Baylor, are modeling and machining an impeller for the pump.

Testing and computer analysis toward further improvements of the VAD are continuing. In 1994, NASA provided additional funding to conduct further animal experiments to the point where the device is ready for human trials; that could come in 1996, if the JSC/Baylor group can find an industrial partner to develop the device for the commercial market. Food and Drug Administration approval is targeted for 1999. The group estimates an initial market for a long term VAD to be more than 60,000 patients a year in the U.S. alone, with a projected 100,000 for future years.








# Software Center

Technology Transfer

In the course of its varied activities, NASA makes extensive use of computer programs, as do other technology generating agencies of the government. To meet their software requirements, these agencies have of necessity developed many types of new computer programs.

These programs constitute a valuable resource available for reuse. Much of the software is directly applicable to secondary use with little or no modification; most of it can be adapted to special purposes at a cost far less than that of developing a new program.

Therefore, American businesses can save time and money by taking advantage of a special service that NASA offers: supplying government-developed software capable of being adapted to new uses. NASA's mechanism for making the software available to business and other clients is the Computer Software Management and Information Center (COSMIC)*.

Located at the University of Georgia, COSMIC gets a continual flow of government-developed software and identifies those programs that can be adapted to secondary usage. The center's library contains more than 1,200 programs for such purposes as structural analysis, artificial intelligence, computational fluid dynamics, thermal analysis, image processing, project management and a great variety of other functions. COSMIC customers can purchase a program for a fraction of the original cost and get a return many times the investment, even when the cost of adapting the program to a new use is included.

An example of how this service aids clients is the use of COSMIC-supplied software by the Society for Computer Simulation International (SCS), San Diego, California, a professional level technical society that distributes information on the methodologies, techniques and uses of computer simulation.

A major SCS program involves frequent conferences and seminars on the latest technological areas wherein simulation is emerging as a significant tool in research, development and testing. A useful aid employed by SCS vice president for North America Mary Lou Padgett in the seminars is a NASA program called NETS (Neural Network Development Tool). Developed by Johnson Space Center, NETS is a software system modeled after the human brain; it is designed to help scientists exploring artificial intelligence to solve problems that involve pattern matching.

The seminars, intended for professional people who are familiar with neural networks to varying degrees, promote technology transfer and encourage those interested in applications to use neural networks like NETS. Padgett gives participants examples that they can manipulate, alter or enhance for their own applications. Padgett, in red **below**, is shown conducting a seminar on NETS usage.

*COSMIC is a registered trademark of the National Aeronautics and Space Administration.

# Publications

An essential measure in promoting greater use of NASA technology is letting potential users know what NASA-developed technologies are available for transfer. This is accomplished primarily through the publication *NASA Tech Briefs*.

The National Aeronautics and Space Act requires that NASA contractors furnish written reports containing technical information about inventions, improvements and innovations developed in the course of work for NASA. These reports provide the input for *Tech Briefs*. Issued monthly, the free publication is a current awareness medium and a problem solving tool for more than 200,000 government and industry readers. It is a joint publishing venture of NASA and Associated Business Publications of New York City.

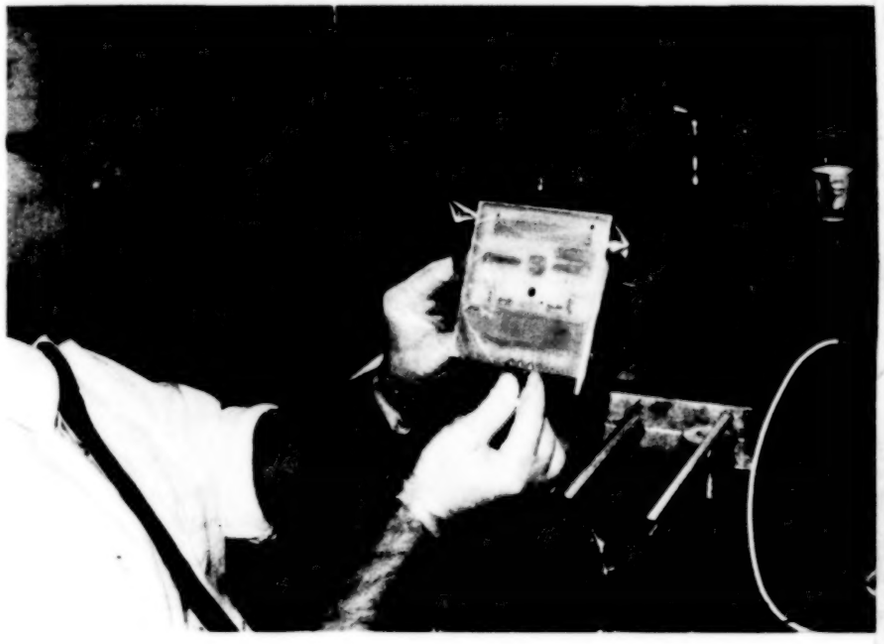
Each issue contains information on newly developed products and processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs, and other innovations originating at NASA field centers or at the facilities of NASA contractors. Firms interested in a particular innovation can get more detailed information by requesting a Technical Support Package (TSP); more than 135,000 such requests are filled annually.

An example of how *Tech Briefs* inspires secondary application of NASA technology is the experience of Trace Laboratories-Central, Chicago, Illinois, a full service independent testing laboratory specializing in testing printed circuit boards, automotive products and military hardware.

Jeffry A. Schutt, general manager of Trace Laboratories-Central, reported that his division used two *Tech Briefs* articles, plus follow-up TSPs from Jet Propulsion Laboratory, to enhance the company's testing process. Specifically, NASA information on "electromigration" was applied to the surface insulation resistance (SIR) testing procedure that Trace Laboratories frequently conducts on printed circuit board materials, such as fluxes and solder pastes (at **right**, a Trace technician is assessing the integrity of a prepared test pattern prior to subjecting it to test). The NASA input helped optimize the SIR testing process without compromising testing data and it allowed Trace to reduce testing time.

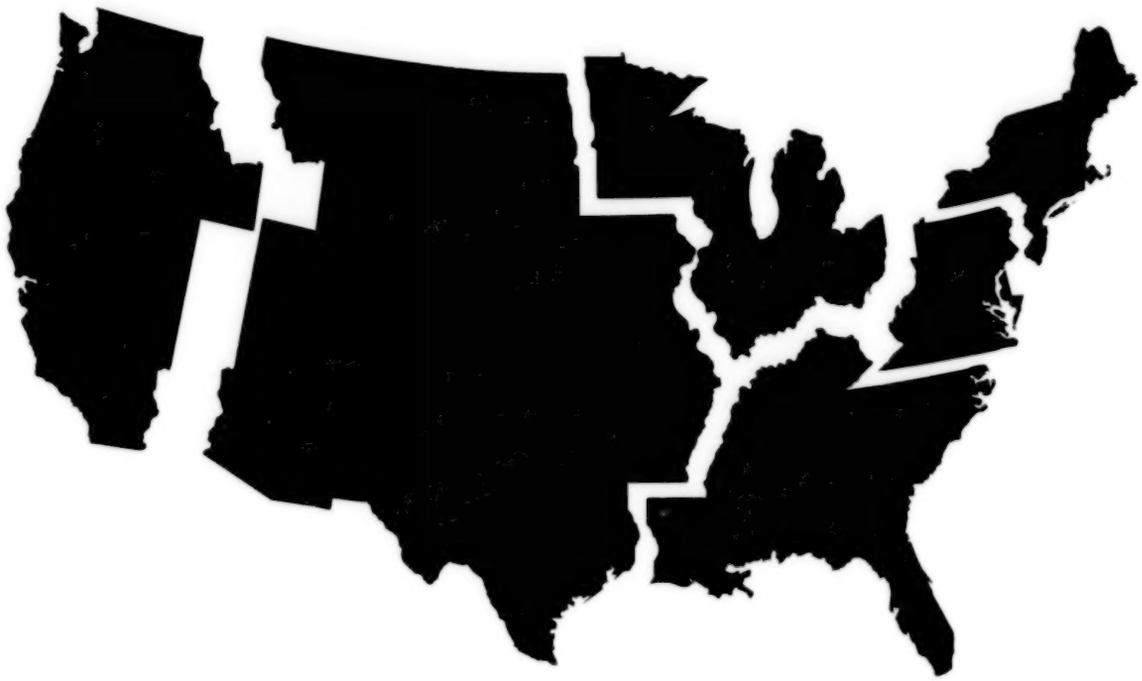
This is important because SIR testing evaluates the effects on electronic materials that have been cleaned by an alternative method to the use of chlorofluorocarbon (CFC) solvents, which electronics manufacturers have used for years to clean components; they are seeking to eliminate CFC solvents, which are to be banned. SIR test data on the durability of parts is used by manufacturers to refine their production processes.

Says Jeffry Schutt: "The Technical Support Packages from NASA reaffirmed much of what we already knew about electromigration but also opened our eyes to other issues that needed to be considered. The information enabled us to improve the quality of the service we provide our customers."



# NASA's Technology Transfer Network

The NASA system of technology transfer personnel and facilities extends from coast to coast. For specific information concerning the activities described below, contact the appropriate technology transfer personnel at the addresses listed, or address inquiries to the Manager, Technology Transfer Office, Center for AeroSpace Information, 800 Elkridge Landing Road, Linthicum Heights, Maryland 21090.



▲ *Field Center Technology Transfer Offices:* manage center participation in regional technology transfer activities.

▼ *National Technology Transfer Center:* national information, referral and commercialization service for NASA and other government laboratories.

■ *Regional Technology Transfer Centers:* information, technical and commercialization services.

● *The Computer Software Management and Information Center (COSMIC):* offers government-developed computer programs adaptable to secondary use.

★ *Application Teams:* assist agencies and private institutions in applying aerospace technology to solution of public problems.

◆ *Technology Commercialization Centers:* industrial incubators for commercialization of NASA technology and development of joint-sponsored research partnerships.

## ▲ Field Centers

*Ames Research Center*
National Aeronautics and Space Administration
Moffett Field, California 94035
Director, Office of Commercial Technology:
Syed Z. Shariq, Ph.D.
Phone: (415) 604-6406

*Goddard Space Flight Center*
National Aeronautics and Space Administration
Greenbelt, Maryland 20771
Technology Transfer Officer: George Alcorn, Ph.D.
Phone: (301) 286-5810

*Lyndon B. Johnson Space Center*
National Aeronautics and Space Administration
Houston, Texas 77058
Director, Technology Transfer and
Commercialization Office: Hank Davis
Phone: (713) 483-3809

*John F. Kennedy Space Center*
National Aeronautics and Space Administration
Kennedy Space Center, Florida 32899
Technology Utilization Officer: James A. Aliberti
Phone: (407) 867-3017

*Langley Research Center*
National Aeronautics and Space Administration
Hampton, Virginia 23665
Technology Transfer Team
Director, Technology Applications Group:
Charlie Blankenship
Phone: (804) 864-6005

*Lewis Research Center*
National Aeronautics and Space Administration
21000 Brookpark Road
Cleveland, Ohio 44135
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William Gasko, Ph.D., director
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FILMED

MAR 22 1995